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UTERO-TUBAL INSUFFLATION,

AN ANALYSIS OF THE RESULTS OF 635 INSUFFLATIONS PERFORMED
BY THE KYMOGRAPHIC METHOD,*

by

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The possibility of non-operative determination of the patency of the Fallopian tubes by means of insufflation was first described by I. C. Rubin in a classical paper on this subject which he read before the Section on Obstetrics, Gynaecology and Abdominal Surgery at the Seventy-First Annual Session of the American Medical Association in April 1920. (1) In his original paper Rubin advocated the use of oxygen for the purpose of the insufflation test, but later he advised the use of carbon dioxide as being more rapidly absorbable from the peritoneal cavity. The original apparatus for the performance of the test was very simple, consisting essentially of a cannula for introduction into the cervix, an oxygen tank and the necessary connections. The volume of gas injected was measured by means of graduated bottles, and the later inclusion of a mercury manometer in the apparatus provided information as to the pressure at which gas passed through the tubes. In 1928 (2) Rubin described a kymographic method of insufflation, the use of which must to-day be considered as indispensable if it is desired to obtain the maximum amount of information regarding the condition of the Fallopian tubes in any particular case.

In October 1934 the writer (3) devised a relatively simple form of kymographic apparatus for the investigation of tubal patency, and since that date some 635 insufflations have been carried out with it. The object of this paper is to summarise the experience gained during the performance of these examinations and to endeavour to indicate the conditions under which the use of utero-tubal insufflation may be of value to the clinician.

* A paper read at a meeting of the Hong Kong Branch of the British Medical Association on August 28th, 1940.

INDICATIONS.

The common indications for the use of the test are as follows:—

- (a) As part of the routine gynaecological investigation of a patient suffering from primary or secondary sterility.
- (b) To aid in the differential diagnosis of an obscure pelvic condition.
- (c) To determine the state of the residual tube after the removal of one appendage for conditions such as tubal pregnancy, ovarian cyst, hydrosalpinx, pyosalpinx, etc.
- (d) To confirm the success of a sterilising operation.
- (e) As a routine post-operative procedure in cases of salpingostomy or tubo-uterine implantation.
- (f) As a therapeutic measure in maintaining or improving tubal patency in certain cases.

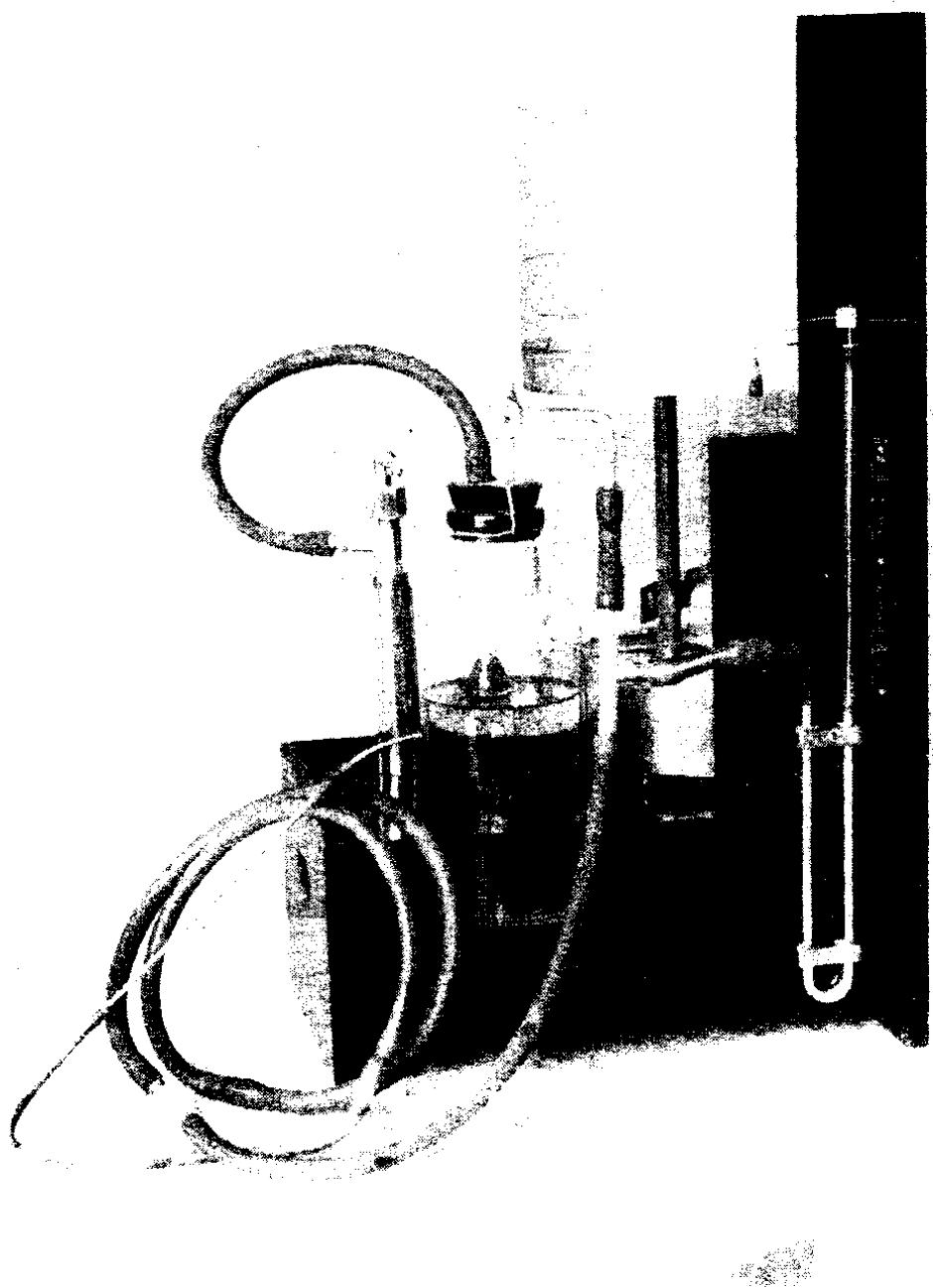
CONTRA-INDICATIONS.

- (a) Menstruation or any other type of uterine bleeding. The most favourable time for the performance of insufflation is between the fourth and seventh days following the cessation of menstruation. Times other than this should be rigidly avoided if it is desired to ensure the complete safety of the procedure.
- (b) Acute or subacute inflammatory conditions of the genital tract. This particularly applies to acute or subacute endocervicitis and to tender inflammatory swellings of the pelvis.
- (c) Pregnancy.
- (d) Severe constitutional disease.

TECHNIQUE.

No special preparation is required and it is unnecessary for the patient to be admitted to the hospital or to be anaesthetised for the test. Nearly all of the 635 tests described were performed on out-patients without any special preparation and without anaesthesia. The patient is placed in the lithotomy position and suitably draped. The position of the uterus and the condition of the pelvic organs should have been determined at a previous examination and the presence of any acute or subacute pelvic infection ruled out. The vaginal walls, cervix and cervical

FIG. 1.



Kymographic Apparatus
for the Determination of Tubal Patency

UTERO-TUBAL INSUFFLATION

Date: O. P. D. No: Years Married Type of Sterility
 Hospital No: Pregnancies (including abortions)

Name: Age:

Date and duration of L.M.P.
 No. of days since cessation of L.M.P.

mm. Hg.

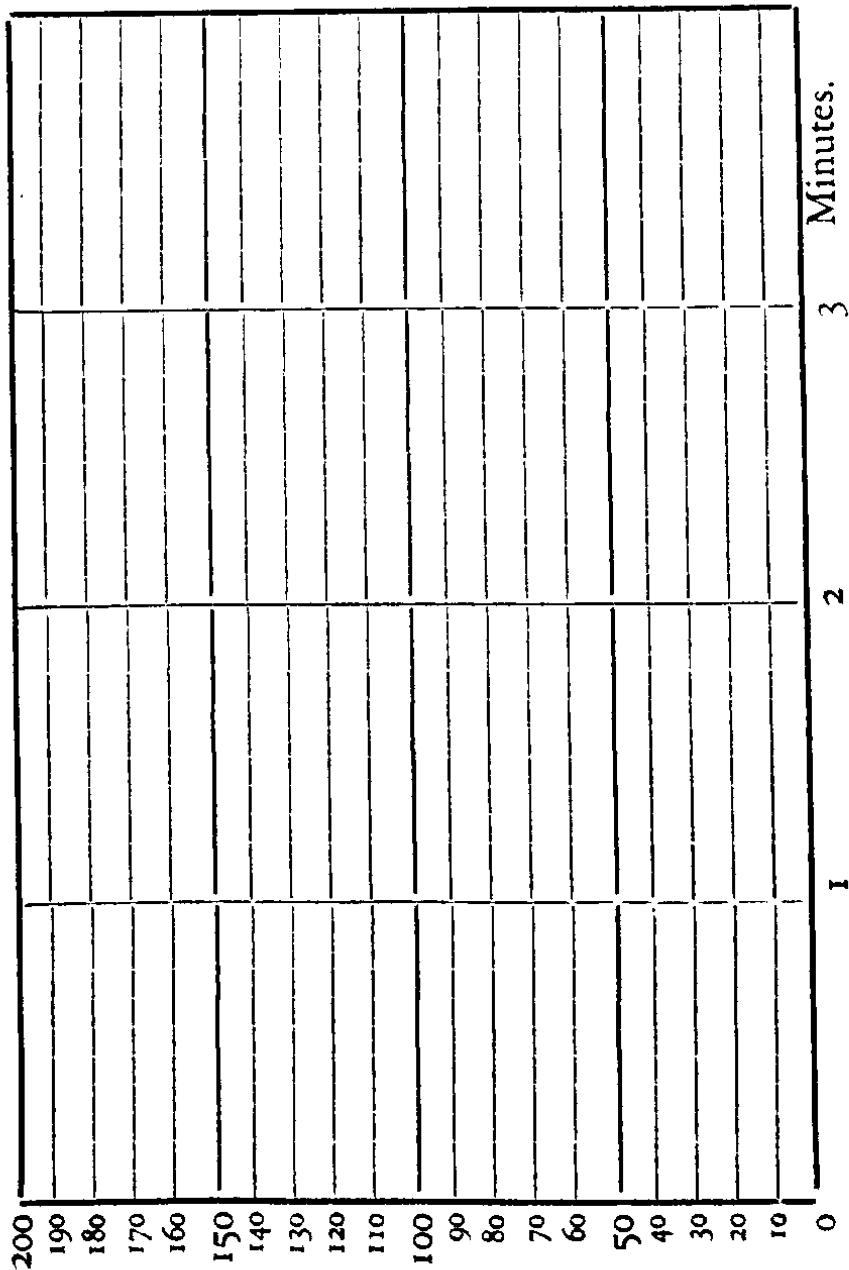


Fig. 2.

Insufflation Performed by
 Strokes of volumeter: Estimated volume of CO_2 injected:

Auscultation: Right Left

Subjective Symptoms:

Fluoroscopy or X-ray

Diagnosis

Follow-up

Physical Findings

canal are now carefully sterilised with 5% Mercurochrome or other suitable antiseptic solution. A light volsellum forceps is gently attached to the anterior lip of the cervix and a sound slowly passed through the external os to determine the length and direction of the uterine cavity. A uterine cannula is then introduced so that the rubber acorn comes into firm contact with the external os. A gas-tight joint is maintained throughout the test by upward pressure on the cannula and counter-traction on the volsellum forceps. The newer type of self-retaining cannula introduced by Colvin (4) is both simple and effective and dispenses with the need for a volsellum. Everything is now ready for connection to be made with the kymographic apparatus. An assistant has meanwhile adjusted the flow of carbon dioxide gas from the sparklet so that the volumeter is emptying at the rate of about two to four times a minute (this represents a flow of about 30 to 60 c.c. of gas per minute). A recording paper is mounted on the drum which is set to rotate at the slow speed of about one and a half inches per minute, and when connection has been made with the cannula the gas valve is turned on and the inked writing arm commences to record the tracing on the drum. During the test one assistant has control of the apparatus and carefully notes the amount of gas which is used while another assistant carefully auscultates (preferably with the double stethoscope) over the two iliac regions for any signs of the passage of gas on one or both sides. The examiner himself sees that no leakage of gas takes place from the cervix and keeps a careful watch over the symptoms of the patient and the movements of the recording needle. The pressure should never be allowed to exceed 200 mg. Hg, and the volume of gas introduced should not exceed 50 to 100 c.c., unless for exceptional reasons. The existence of normal patency can often be demonstrated with as little as 30 to 50 c.c. of gas. When the test is finished the valve is turned to the appropriate position, the drum is brought to a standstill and the needle allowed to return to the resting level. A permanent record of the test is then available and should be included in the patient's notes and preserved for future reference (see Fig. No. 2).

RESULTS.

The results obtained in the whole series are summarised in Table No. I. It will be noticed that one of four types of result may be obtained in any given case, and the nature of the graph will show clearly and decisively to which category the case belongs. The four possibilities are (a) normal tubal patency, (b) tubal spasm, (c) tubal stenosis and (d) complete tubal obstruction. The characteristic features of each of these four conditions will be discussed in turn, and for the purpose of deducing the frequency of the various types the two

big groups of first examinations in sterility cases, comprising 544 patients in all, will be used.

TABLE I.
Results of 635 Utero-Tubal Insufflations.

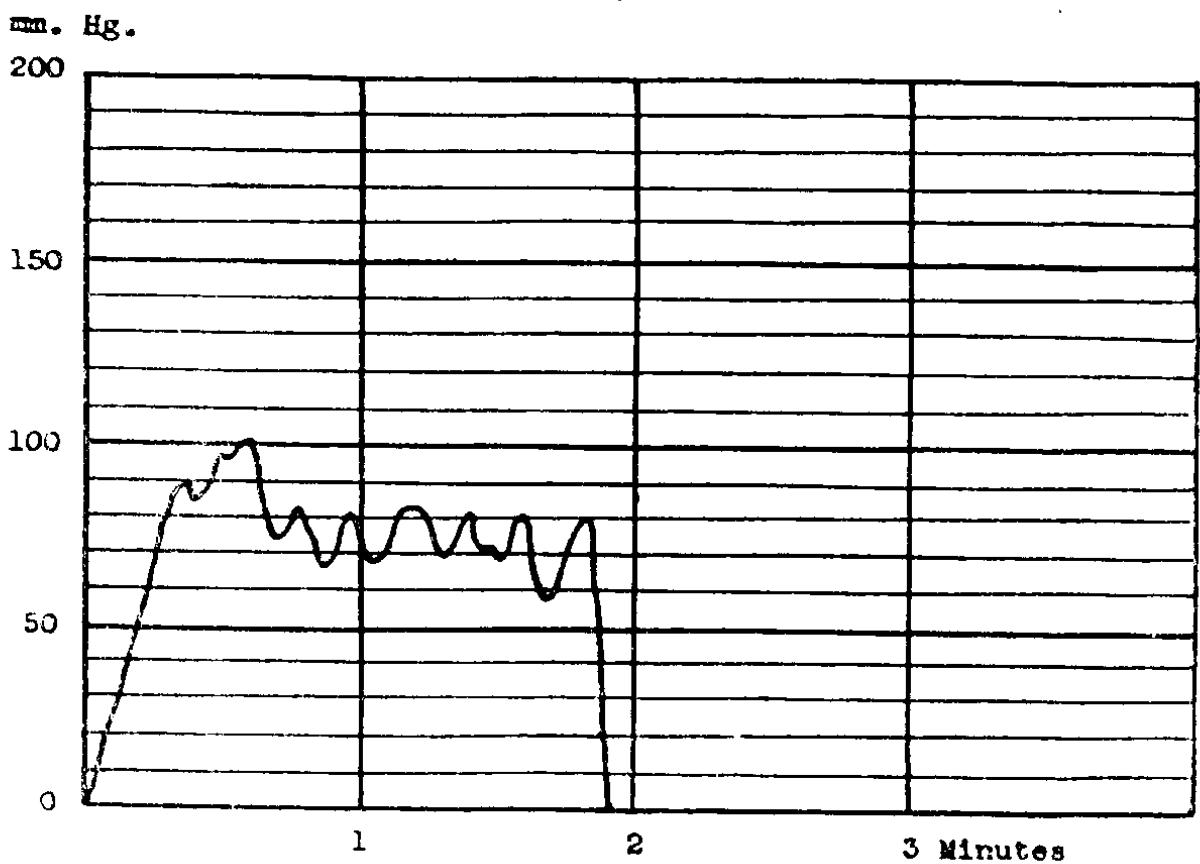
Indication.	Normal Patency	Spasm	Stenosis	Blocked	Total
Primary Sterility	170	12	30	101	313
Secondary Sterility	102	7	38	84	231
Repeat Examinations	18	—	11	22	51
After Salpingostomy or tubo-uterine implantation	9	—	5	2	16
To determine state of residual tube after removal of one appendage for :					
(a) tubal pregnancy ...	5	—	1	4	10
(b) ovarian cyst	5	—	—	2	7
After Caesarean Section :					
(a) to confirm fact of sterilisation	—	—	—	2	2
(b) to determine if still patent	1	—	—	—	1
Miscellaneous Indications....	4	—	—	—	4

Total Number of Insufflations : 635

(a) *Normal Tubal Patency.*

Normal patency was found in 50% of the cases investigated. The type of graph produced in such a case is well shown in Fig. No. 3. At a pressure between 75 and 100 mm. Hg. gas commences to pass through the tubes in the average case and well marked oscillations in the curve are seen to occur at the rate of three to five times per minute, or sometimes more frequently. These oscillations, which do not occur in cases of complete blockage of the tubes, have been shown to depend upon rhythmic peristalsis of the tubal musculature. Seckinger

Fig. 3.



Normal Tubal Patency of average type. Over 50 per cent of normal tubes show patency at pressures between 75 and 125 mm. Hg. (Case No. 466).

and Snyder (5) demonstrated in 1926 that strips of isolated human tubal musculature are capable of such contractions, and that the frequency and amplitude of these contractions increase as the time of ovulation approaches. Rubin and Bendick (6) have observed, and taken X-ray photographs of, these contractions during the course of lipiodol examinations. Wimpfheimer and Feresten (7) in an interesting study of the uteri and tubes of 60 living rabbits, showed that the undisturbed uterus and tubes undergo rhythmic peristaltic movements. During utero-tubal insufflation they showed that when the uterus became distended its motion was reduced or disappeared: the tube, on the other hand, showed no visible distension and its motion was unaltered. In clinical use one of the great advantages of the kymographic method of insufflation is that it provides this most important information as to the healthy condition or otherwise of the muscular wall of the tube.

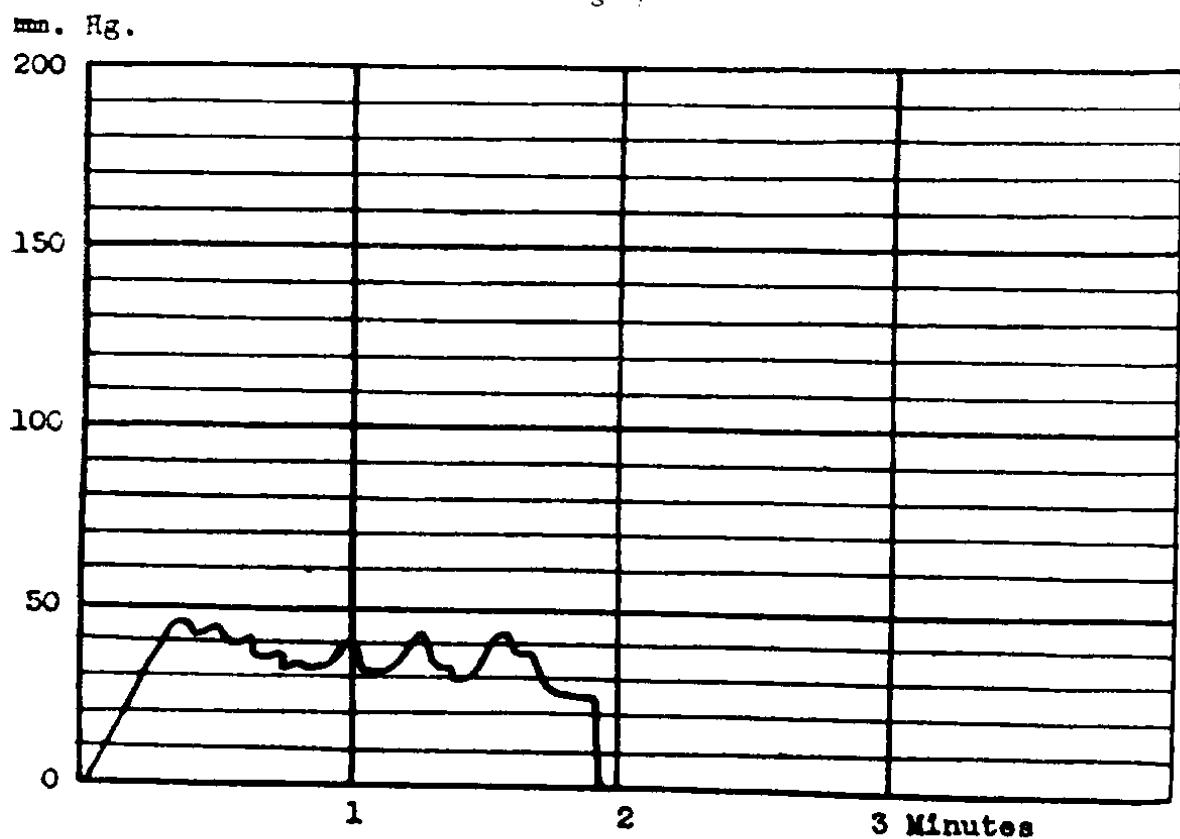
The pressure at which gas commences to pass through the average normal tube is usually between 75 and 100 mm. Hg. There is considerable variation in this, however, as is shown from the analysis of a large number of cases of normal patency given in the following table:—

TABLE II.
*Degree of Pressure Necessary to Demonstrate Tubal Patency
 in 272 Patients with Normal Tubes.*

<i>Degree of Pressure Required.</i>	<i>Cases</i>	<i>Per Cent.</i>
Below 50 mm. Hg.	15	5%
Between 50 and 75 mm. Hg.	43	16%
Between 75 and 100 mm. Hg.	90	33%
Between 100 and 125 mm. Hg.	60	22%
Between 125 and 150 mm. Hg.	40	15%
Over 150 but below 200 mm. Hg.	24	9%
Total:	272	100%

It will be noticed that 55% of the cases show patency between 75 and 125 mm. Hg. Fig. No. 4 shows a case of patency at low pressure and Fig. 5 shows a graph taken from the other end of the scale. In a paper published in

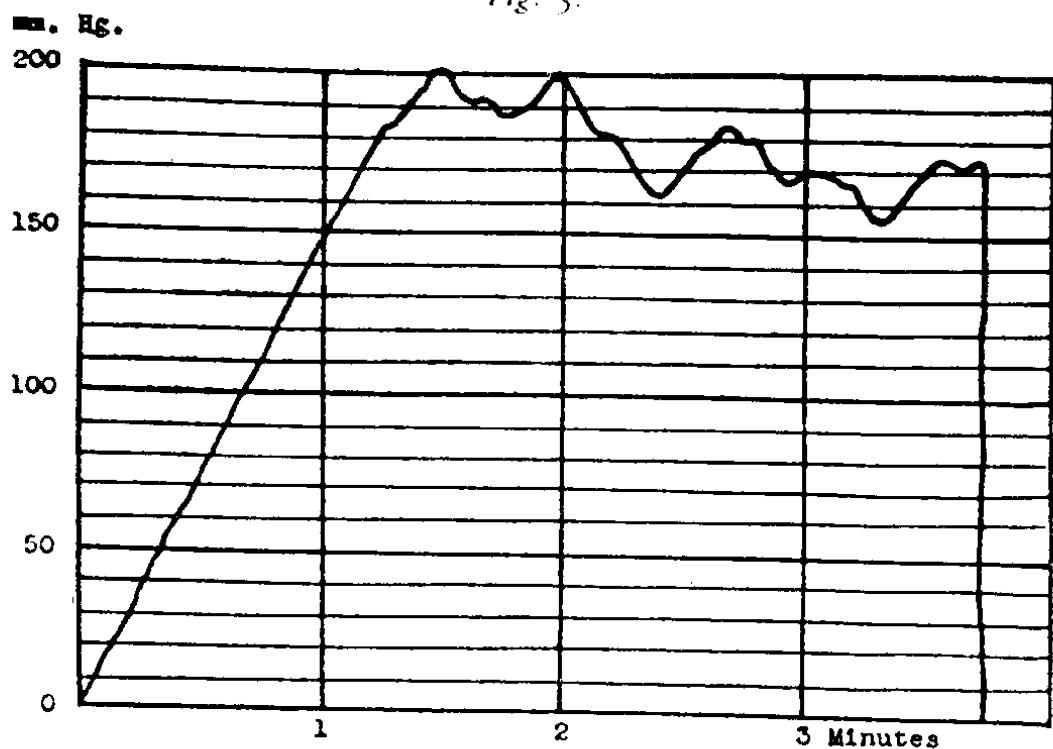
Fig. 4.



Normal tubal patency at low pressure. Only about 5 per cent of normal tubes show patency at pressures below 50 mm. Hg.

(Case No. 575).

Fig. 5.



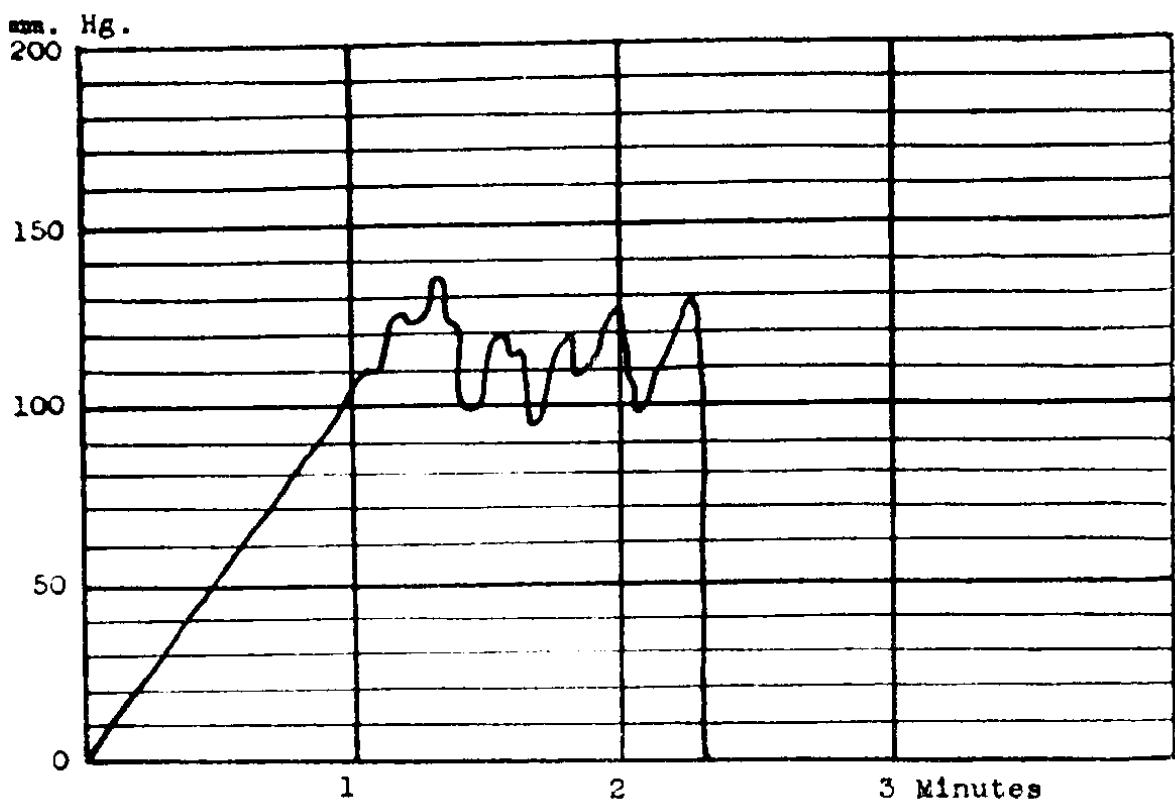
Normal tubal patency at high pressure. In about 9 per cent of normal tubes patency can be demonstrated only at pressures between 150 and 200 mm. Hg. (Case No. 190)

1934 Goodall (8) maintained that patency at extremely low pressures predisposes to infection of the peritoneal cavity, and he cited a series of five cases in support of this theory. The theory sounds a rational one, but it should be added that no cases have been encountered in the course of the present investigation which would lend support to the contention.

A point of interest is that the tubal contractions become greater in frequency and amplitude as the date of ovulation approaches, and during the few succeeding days. Insufflation is not usually performed as late as the 14th day of the cycle, but Fig. No. 6 shows the type of contraction referred to. The graph was obtained on the 11th day of the cycle.

One other question which occasionally arises is with regard to the type of graph obtained when only one tube is patent. The graph differs in no appreciable way from that of a case of bilateral tubal patency. A possible method of differentiation is to be found in the use of the double stethoscope, as suggested by the writer a few years ago (9). In the majority of cases a clear distinction is possible by the use of this method. Fig. No. 7 shows a characteristic graph in a case of unilateral tubal patency.

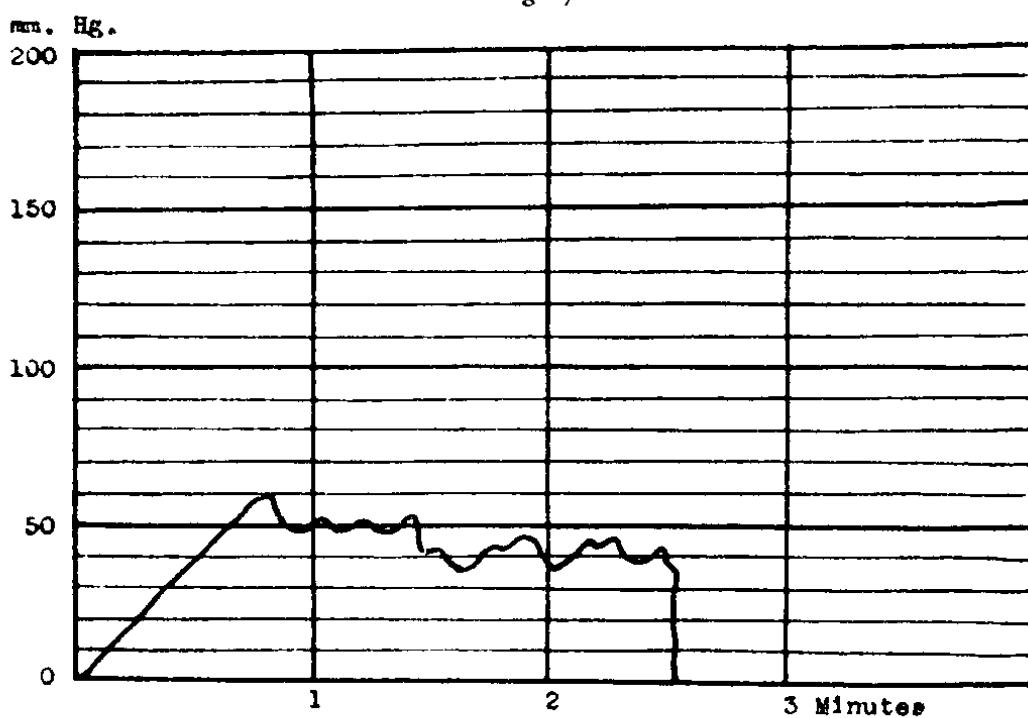
Fig. 6



Normal tubal patency showing wide range of contractions.

Contractions become more frequent and of wider amplitude as the time of ovulation approaches. Test performed on eleventh day of cycle. (Case No. 200).

Fig. 7.



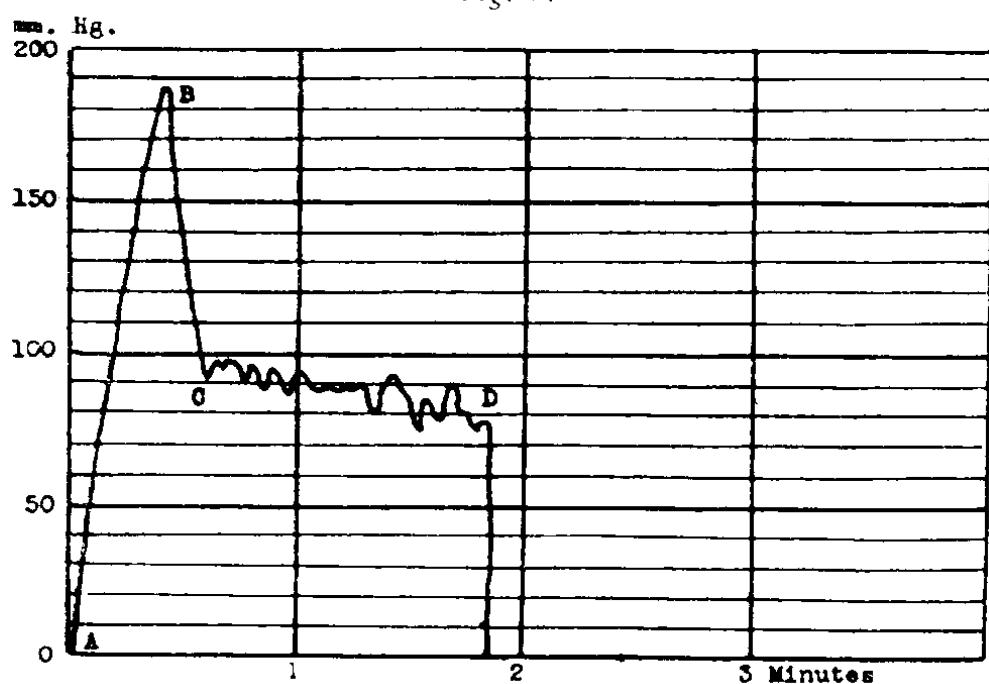
One sided tubal patency shows essentially the same findings as bilateral patency.

The above graph was obtained in a case where the left appendage had been completely removed together with an ovarian cyst weighing over forty pounds. Nineteen days after the operation the above picture showed normal patency of the residual right tube.
(Case No. 146).

(b) *Tubal Spasm.*

Only 19 cases of tubal spasm were encountered in the whole series. This is equivalent to an incidence of 3.5% of all cases investigated, as compared with Rubin's figure of 4%. Fig. 8 shows an excellent example of the graph provided by such a case. Owing to the high tonicity of the sphincter-like muscle at the utero-tubal junction gas cannot pass until a high initial pressure is reached. Thereafter there is a rapid fall in the pressure level (amounting to nearly 100 mm. Hg. in this instance), after which a graph typical of normal tubal patency is shown. The injection of atropine will abolish the spasm and is followed by a patency graph indistinguishable from the normal. It is difficult to estimate the clinical importance of spasm in relation to sterility, but it is open to question whether it offers any serious obstruction to the passage of spermatozoa or ova.

Fig. 8.



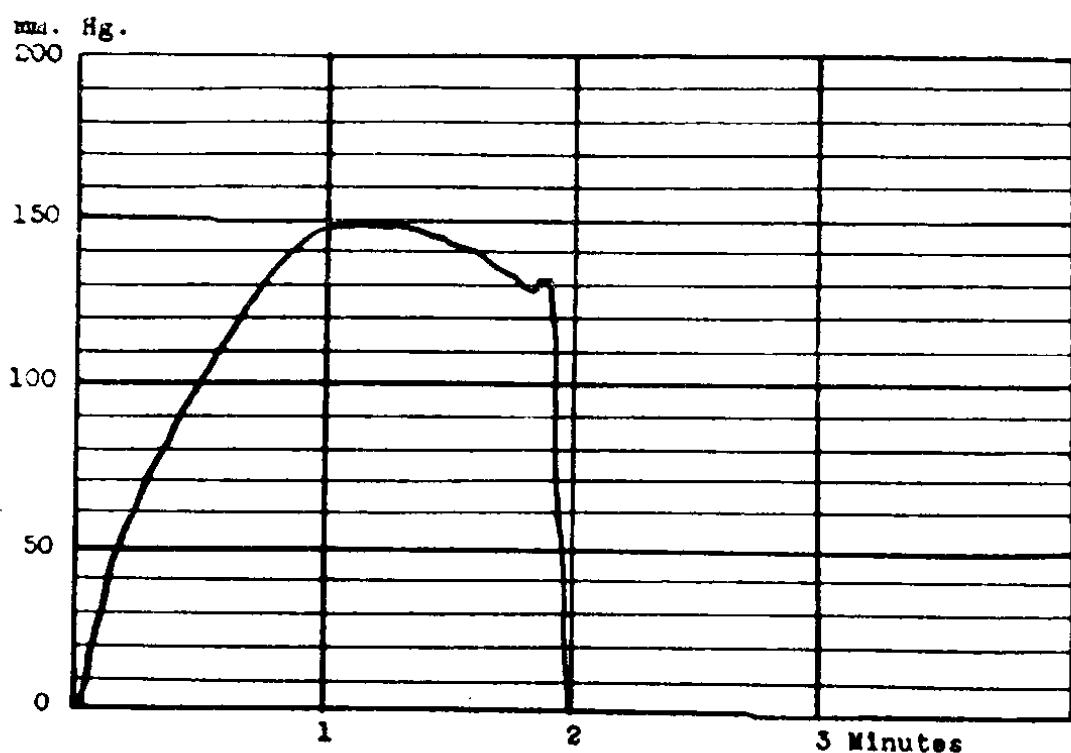
Tubal Spasm. This type of graph only occurs in about 4 per cent of cases. It is characterised by a high initial rise from A to B, at which point there is relaxation of the muscle at the utero-tubal junction, with a rapid fall of the curve to a lower level. From C to D the curve is of the normal type, with well marked tubal contractions. (Case No. 529).

(c) *Tubal Stenosis.*

By tubal stenosis we understand a tube whose lumen is narrowed or partially obliterated. Such a condition is brought about mainly by inflammatory processes, with resulting thickening and fibrosis of the tube wall and nodules, strictures or kinks

of the tube, with or without peri-tubal adhesions. Tubal stenosis offers one of the most interesting fields of study opened up by the kymographic method. Tubal stenosis was found to be present in 12.5% of all cases of sterility, and it has a high causal relationship to the failure to become pregnant. It is just in this type of case that the value of the kymograph is most apparent, as the diagnosis of stenosis is not made on the basis of patency or non-patency but on the basis of the functional capacity of the tubes. The feature which is common to all cases of tubal stenosis is the absence or marked impairment of tubal contractions. Patency is present, usually at a higher level than normal, but the type of graph obtained is totally different from the normal one. Investigation by the method of lipiodol or skiodan injection would totally fail to demonstrate this type of abnormality and many such cases would undoubtedly be confused with those of normal patency. The graph in a mild case of stenosis would

Fig. 9.



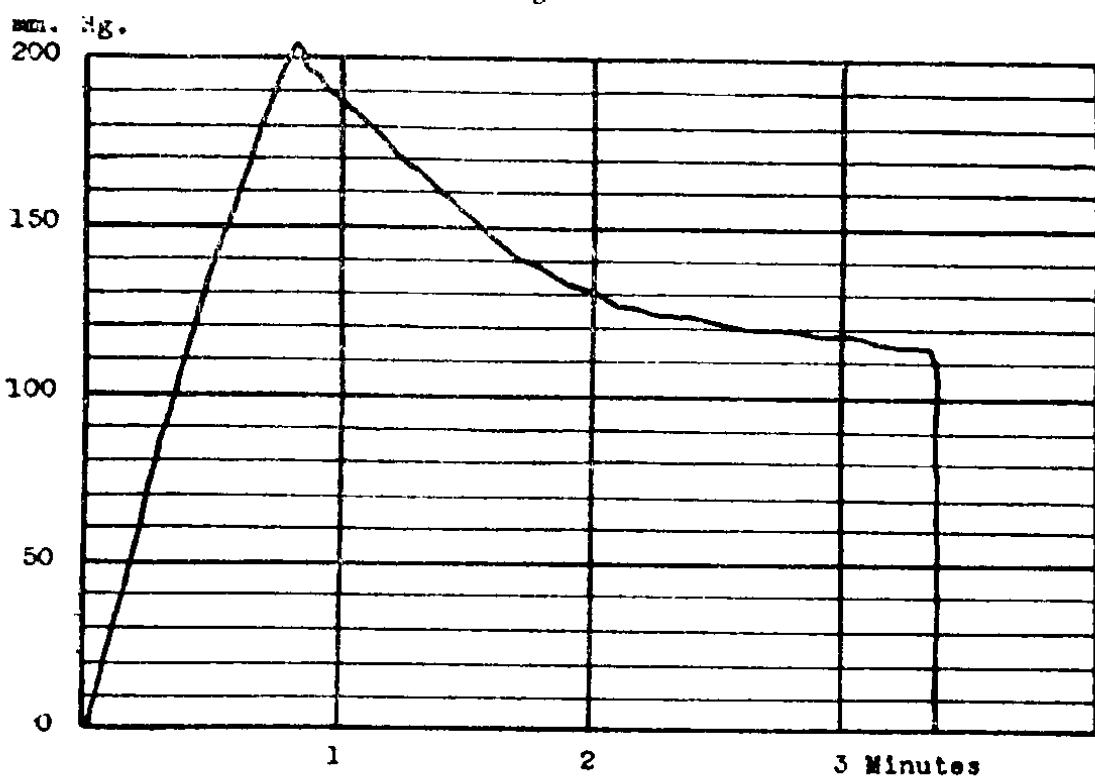
Tubal Stenosis.

This curve is typical of a moderate degree of tubal stenosis. Gas commences to pass at about 150 mm. Hg., and there is absence of tubal contractions. The patient was aged 30 and had been married 12 years, but had had no pregnancy except a premature still-birth 11 years previously. Only the left tube was patent: the patient developed bilateral shoulder pain after the insufflation. (Case No. 438).

show an impairment of the normal peristaltic contractions of the tubes, the contractions being shallower and less frequent than normal. In the more severe cases there is a complete absence of contractions: gas passes only at a relatively high pressure, and on auscultation the gas is heard to be flowing in a steady stream

rather than in the intermittent bursts to be heard in the normal case. The type of curve produced varies considerably. Fig. No. 9 shows a common finding: the curve reaches a height of 150 mm. Hg. and a complete absence of tubal contractions will be noticed. In Fig. No. 10 a more advanced condition is shown: here gas failed to pass until a pressure of 200 mm. Hg. was reached, and then on ceasing to make further injection, gas passed slowly through the tubes causing a steady fall of pressure. The picture produced indicates a high degree of stenosis. It is noteworthy that insufflation, which is normally a practically painless procedure, is associated with a definite degree of discomfort or even pain in many cases of stenosis. In the only two cases of the whole series where any cause for alarm arose during the performance of the test, tubal stenosis was present (see below). In most cases the pain is due to the stretching of adhesions, and it is wise to discontinue the injection if the patient makes any serious complaint.

Fig. 10.



Tubal Stenosis.

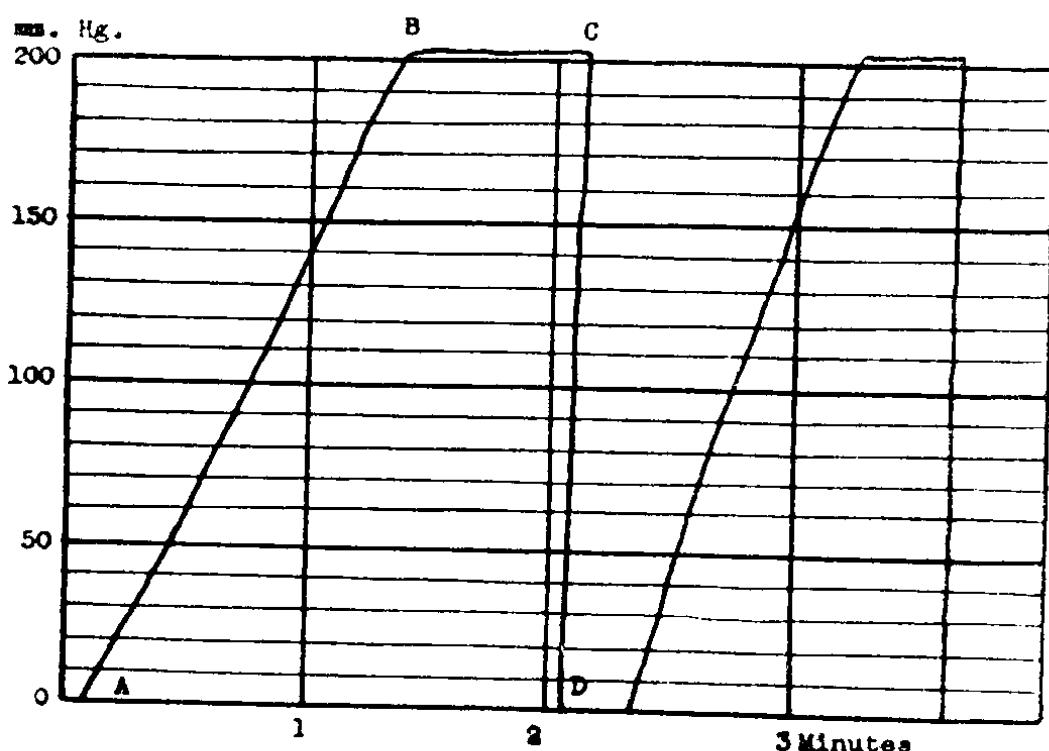
A high degree of stenosis is present in this case (a woman of 34 suffering from secondary sterility for 9 years). Injection of gas ceased at the peak of the curve and gas then passed slowly through the tubes. (Case No. 490).

(d) Complete Tubal Obstruction.

Complete non-patency of the tubes was found in 34% of the series, a figure which corresponds closely to that of Rubin's. The graph obtained in such cases, of which an example is shown in Fig. No. 11, is absolutely characteristic and can have no

other interpretation than that of complete tubal non-patency at the pressure reached. (It should be noted that non-patency of one tube only produces no characteristic graph, as the picture is dominated by the condition of the other tube whether normally patent or stenosed). Tubal occlusion may be present (i) at the utero-tubal junction, (ii) beyond the utero-tubal junction but without marked hydrosalpinx and (iii) at the fimbriated extremity with hydrosalpinx formation. (i) In the first instance the graph rises steadily to 200 mm. Hg., as shown in Fig. No. 11: on discontinuing the injection the pressure remains steady, and returns to normal on releasing the gas. There is no passage of gas heard through the stethoscope, and no pneumo-peritoneum can be demonstrated after the test. Pain, if present, is of the central abdominal type due to distension of the body of the uterus. (ii) In the second type of case exactly the same results are noted, but the patient may complain of a painful sensation developing in one or both iliac fossae, disappearing when the pressure is released. (iii) If a definite hydrosalpinx is present insufflation is, generally speaking, contra-indicated. In some cases the condition escapes clinical detection and insufflation is performed. If the interstitial portion of the tube is patent there is then a danger of gas being forced into the already distended

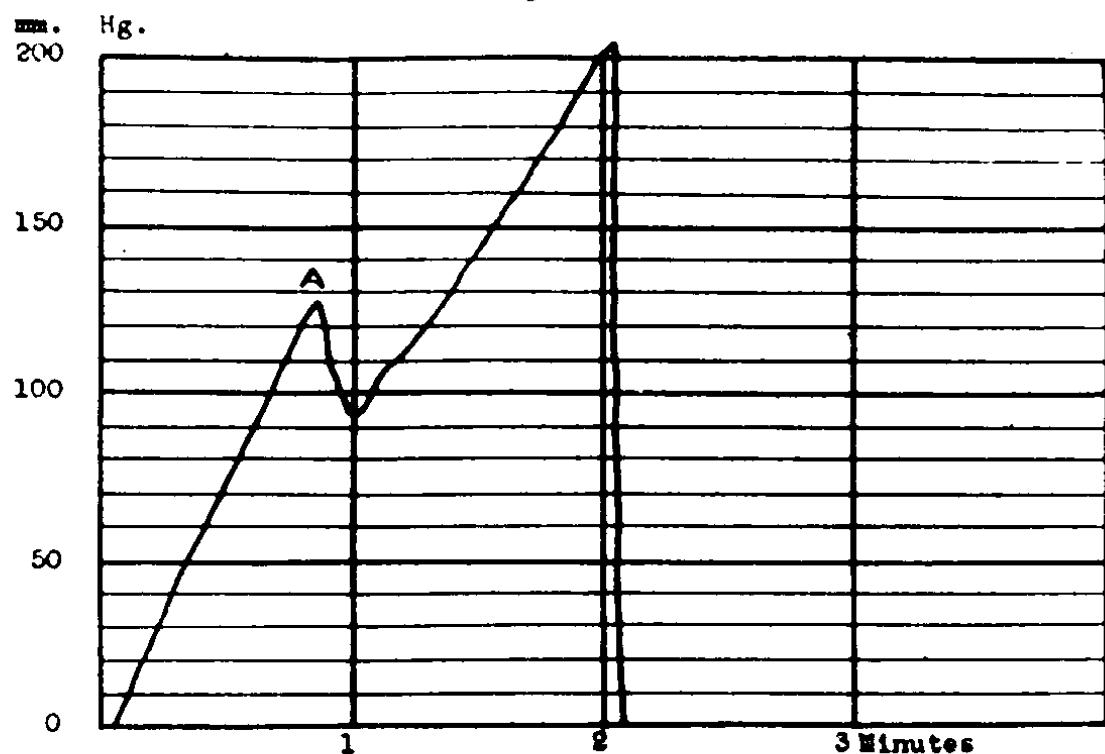
Fig. 11.

Typical graph showing complete tubal obstruction.

In the absence of leakage of gas from the cervix or through the Fallopian tubes the graph rises steadily in a straight line from A to B. On shutting off the gas intra-uterine pressure remains constant from B to C, and on releasing the pressure there is a rapid fall to D. (Case No. 627).

tube and producing a pneumo-hydrosalpinx. This is invariably accompanied by the development of considerable pain in the iliac region on the side involved. A transient drop in the pressure is shown on the graph (see Fig. No. 12) and at the same time a small rush of gas may be heard over one tube. After the test a tender swelling may be palpated in one or both fornices, and in two cases of the series the X-ray showed the presence of gas in these swellings.

Fig. 12.



Complete tubal obstruction with pneumo-hydrosalpinx formation.

Severe pain developed over the left lower quadrant at the point A, and at the same time a small rush of gas was heard. After this no further gas passed. After the test X-ray examination showed the presence of gas in a tender swelling in the left fornix, and a diagnosis of pneumo-hydrosalpinx was made. (Case No. 37).

SYMPTOMS EXPERIENCED DURING THE TEST.

The symptoms that may be experienced by the patient during the performance of the test may be classified as follows:—

(a) *Abdominal Discomfort.*

A patient will occasionally report mild hypogastric discomfort as the gas distends the cavity of the uterus. This may be succeeded by slight iliac discomfort as the gas passes into the lumen of the tubes, and usually ceases in patent cases when the gas passes on into the peritoneal cavity. Thereupon a mild umbilical or epigastric discomfort may ensue, but is not of frequent occurrence. As a rule patients with normal tubal patency seldom make any complaint during the performance of tubal insufflation.

and then only in the case of unusually sensitive women. The sensation is frequently likened to that experienced at the onset of a menstrual period.

(b) *Abdominal Pain.*

Abdominal pain, as distinguished from abdominal discomfort, indicates a definite abnormality of the tubes, and usually does not develop until a pressure of over 100 mm. Hg. is reached. *Central pain* in the hypogastric region is an indication of blockage at both utero-tubal junctions although it is not very frequently complained of. It increases as the pressure rises towards 200 mm. Hg., and disappears immediately on release of the pressure. *Lateral pain* may be experienced on one or both sides and indicates one of several possibilities. Complete blockage at the fimbriated extremity, with hydrosalpinx formation, will give rise to symptoms described in a previous paragraph. Incomplete blockage due to stenosis of the tube can also give rise to a considerable degree of lateral or bilateral pain, if gas passes through at a relatively high pressure. In other cases, where peri-tubal adhesions are present the passage of gas may be associated with the breaking down of adhesions, which again results in painful sensations. Generally speaking the development of real pain during the performance of the test is an indication for discontinuance of the insufflation. The pain usually disappears on ceasing the insufflation. If it persists it is a sign that some of the gas is still entrapped or that adhesions have been disturbed. A bimanual examination after the test may reveal a tender swelling not present before and which must be regarded as a pneumo-hydrosalpinx.

(c) *Shoulder Discomfort (Omalgia).*

This symptom is of great confirmatory value in patent cases, and is due to the somewhat irritant effect of the presence of gas on the under surface of the diaphragm. It usually appears when the patient rises from the table and is only of transitory duration, as the CO₂ is rapidly absorbed from the peritoneal cavity. In 157 patients of this series who definitely reported the symptom the shoulder pain was bilateral in 40%, right sided in 34%, and left sided in 26%. The symptom is almost constantly present in patent cases, and may be produced by a small volume of gas, such as 50 c.c. Not every patient will complain of the shoulder discomfort, as it is very slight in many cases, but nearly every case of tubal patency will admit the presence of the symptom if questioned. The side or sides upon which discomfort appears is no indication as to whether the right or left, or both, tubes are patent.

SIGNS WHICH HAVE A DIAGNOSTIC VALUE WHEN USED IN CONJUNCTION WITH INSUFFLATION.

(a) *Auscultation.*

Useful information may be gained by listening over the iliac regions with a stethoscope during the insufflation. In normal cases the passage of gas through the tubes will be heard as short intermittent bubblings corresponding with each fall in pressure shown on the graph. In cases of tubal stenosis the character of the sound alters, and, in the absence of tubal peristalsis, assumes a continuous, rather high pitched, whistling character. If a double stethoscope is available (an instrument first suggested by Scott Alison in 1858), it will be found that an accurate distinction between unilateral and bilateral patency can be made.

(b) *Fluoroscopy or X-ray Examination.*

This will demonstrate the presence of a sub-diaphragmatic pneumo-peritoneum in all cases in which gas passes through the tubes, with but very rare exceptions. This sign provides absolute confirmation of tubal patency. Out of 114 cases in which fluoroscopy was carried out after the test, 58% were found to have bilateral sub-diaphragmatic pneumo-peritoneum, 24% had gas under the left dome of the diaphragm and 18% had gas under the right dome only. No relationship was found to exist between the side on which the gas was found and the side on which the tube was patent. A bilateral sub-diaphragmatic pneumo-peritoneum was often observed when only one tube was patent. On the other hand a definite relationship existed between the side of the diaphragm under which air was found and the side of the shoulder pain. On several occasions a definite pneumo-peritoneum was demonstrated with no shoulder pain. It was observed that gas under the left side of the diaphragm was more likely to produce pain in the corresponding shoulder than gas under the right side.

DANGEROUS ACCOMPANIMENTS AND SEQUELAE.

Very few untoward reactions were noticed in the 635 insufflations reported in this paper. A careful record was kept of all cases in which unusual symptoms occurred, and the following classification is made of them:—

(a) *Pain.* Insufflation was stopped on account of severe pelvic pain in 5 cases. These were probably cases of hydrosalpinx or severe stenosis with adhesions. The development of severe pelvic pain is a contra-indication to the continuance of the test.

(b) *Nausea.* There were 5 cases in whom the test induced nausea. In one other case there was *retching*, and in another *vomiting* occurred. In all these cases the symptoms were only transitory and the patients rapidly recovered their equilibrium.

(c) *Vertigo.* In 3 cases the patients complained of dizziness which lasted for a short time after the performance of the test.

(d) *Fainting.* One patient, of a rather neurotic tendency, fainted for two minutes immediately after the test.

(e) *Hysteria.* One patient showed signs of hysteria which rapidly subsided.

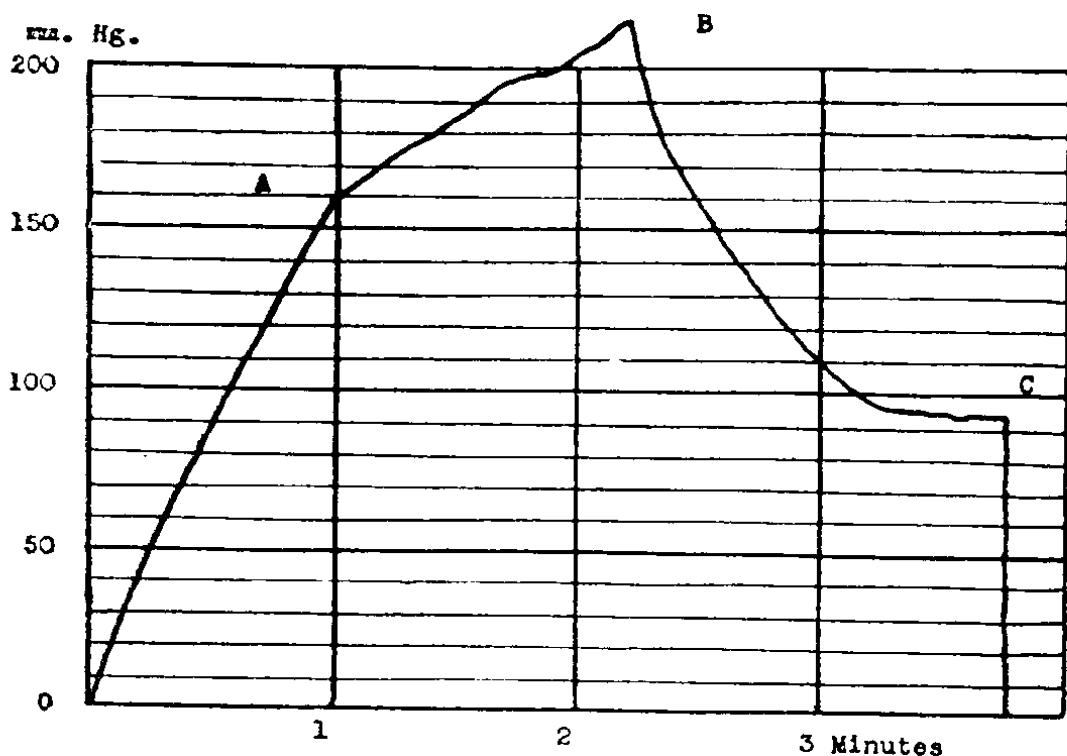
(f) *Gas Embolism.* In only 2 cases of the series was there any serious cause for alarm, and in both of these the possibility of gas embolism was suspected although not proven. In both cases the symptoms subsided after a brief period.

Rare cases of gas embolism have been reported by half-a-dozen authors, including Moench (10) and Mansfeld and Dudits (11). It is an exceedingly rare complication and if the contra-indications for the performance of the test are properly observed, and the amount of gas injected strictly controlled, it should never cause an untoward result. The two cases of suspected gas embolism just referred to are of sufficient interest to justify the inclusion of a detailed note upon each.

First Case of Suspected Gas Embolism (Case No. 224).

The patient was a Chinese married woman of 29 and came complaining of secondary sterility of 5 years duration. She had been married 9 years and had had 2 previous pregnancies. The uterus was normal in size and shape, the cervix was normal, and there was no swelling or other abnormality in either fornix. A smear from the cervix showed no infecting organisms. The last menstrual period was on March 24th, 1936 and insufflation was carried out on April 3rd (the 10th day of the cycle). The graph (see Fig. No. 13) rose steadily to 155 mm. Hg. when the rise became less rapid, although still maintaining a uniform rate. Gas was shut off when a pressure of 210 mm. Hg. was reached, and steadily fell to a pressure of about 93 mm. Hg., where it remained stationary. In order to effect the rise to 210 mm. Hg. a volume of about 105 c.c. of CO₂ was used. The estimated volume to produce a pressure of 93 mm. Hg. was 38 c.c., so that 67 c.c. of gas needed accounting for. Some faint sounds of bubbling were heard over the right lower quadrant, but no definite sounds over the left. There was no regurgitation from the cervix. During the test the patient complained of epigastric discomfort. Examination after the test showed a normal condition of the pelvic organs, with no distension or tenderness in either fornix.

Fig. 13.



First case of suspected gas embolism. (See text).

The curve rose steadily until the point A was reached, when some gas commenced to pass. At point B the injection was discontinued and the pressure fell steadily until the point marked C, when the cannula was withdrawn. The patient developed cough, dyspnoea, praecordial pain and tachycardia, with cyanosis for about twenty minutes, after which the symptoms completely subsided. (Case No. 224).

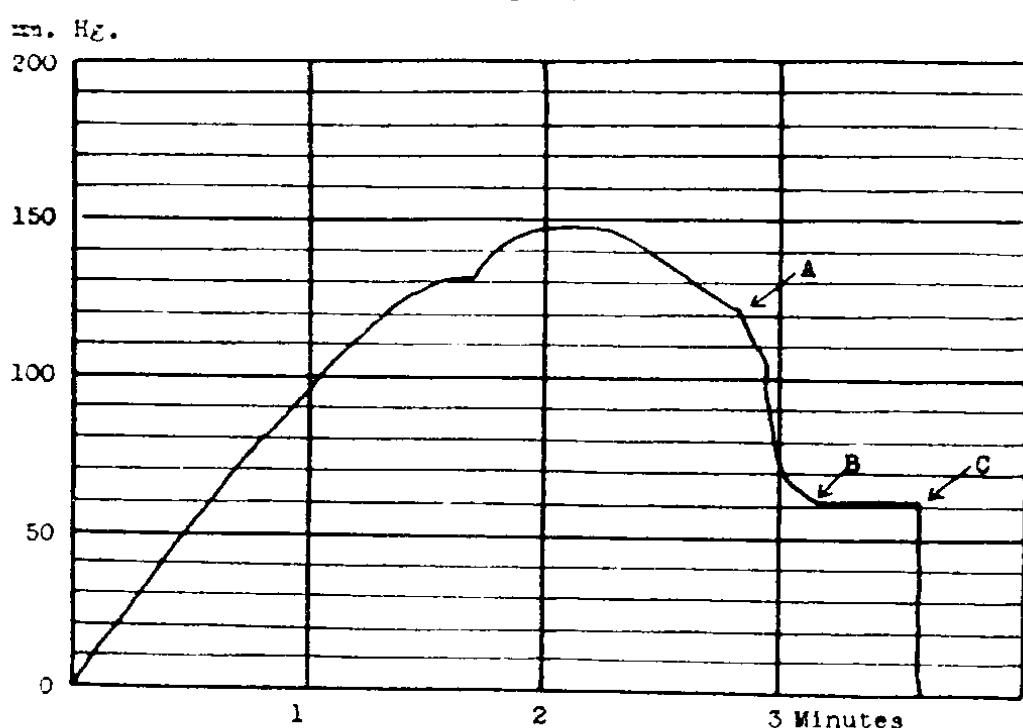
On rising from the table the patient complained of considerable malaise and praecordial pain, and also commenced to cough violently. She was placed on a couch with the head slightly raised and given a stimulant. The pulse rate increased to 112 per minute and, on auscultation over the praecordium, the heart action was found to be very vigorous and regular. A few gas sounds could be heard over the praecordium, but on auscultation with the double stethoscope it was found that these were being transmitted from the stomach. The cough, dyspnoea and chest pain, associated with mild cyanosis of the face, continued for about 20 minutes. The cough produced a moderate amount of frothy sputum, which was noticed to be blood-stained on two occasions. After 20 minutes the symptoms subsided, the pulse rate dropped to 70 and the patient felt perfectly normal again. After a further 20 minutes she was allowed to rise. There were no further symptoms. No shoulder pain and no other discomfort were complained of. Fluoroscopy showed no free gas below the dome of the diaphragm.

A tentative diagnosis of carbon-dioxide gas embolism of the right utero-ovarian veins was made in this case.

Second Case of Suspected Gas Embolism (Case No. 555)..

The patient was an Indian married woman of 25, somewhat highly strung. She had been married for over $3\frac{1}{2}$ years and had had one pregnancy terminating in a premature still-birth 3 years previously, since which time there had been no other pregnancy. The uterus was normal in size, shape and position, and pelvic examination revealed no abnormality of any other organs. The last menstrual period was from September 17th to 24th, 1939 and insufflation was carried out on October 2nd (the 16th day of the cycle, and a rather later date than is customary). The graph (see Fig. No. 14) showed

Fig. 14.



Second case of suspected gas embolism. (See text).

The graph shows the appearance usually associated with stenosis. The injection was discontinued at the point A, and pressure then dropped to B, remaining steady until the cannula was withdrawn at the point C. The test was followed by symptoms of severe irritative cough, praecordial discomfort and bradycardia, from which the patient rapidly recovered. (Case No. 555).

the appearance usually associated with tubal stenosis. At the point A the injection was discontinued and the pressure then dropped to B, remaining steady until the cannula was withdrawn at the point C. Altogether a volume of 75 c.c. of gas was introduced. No definite sounds were heard over the right iliac region but some bubbling sounds were audible over the left iliac fossa. There were no remarkable symptoms during the actual insufflation. Two minutes after the injection had ceased a severe irritative cough began, with a feeling of discomfort in the praecordium. The pulse was 72 per minute, the heart sounds were normal and the lungs were normal on ordinary examination. Ten minutes later the pulse dropped to 42

per minute and the patient still showed signs of distress. Stimulants were administered and the patient gradually improved, until she became perfectly normal again. Four hours after the insufflation the pulse rate was 84 per minute and the patient appeared normal in every way. In this case, also, a tentative diagnosis of gas embolism was made, although the possibility of reflex vagal stimulation from peritoneal irritation caused by the test was considered. If gas embolism was present only about 45 c.c. of gas could have been involved as at least 30 c.c. of gas would be needed to create the pressure of 60 mm. Hg. which was shown by the graph at the end of the test.

It will be noticed that in both of these cases graphs indicating tubal stenosis were obtained. In neither case did any unusual symptoms occur during the performance of the test: it was only afterwards that any alarming symptoms developed. In the one case 67 c.c. of gas needed accounting for, and in the other case 45 c.c. In the first case none of the gas could be demonstrated beneath the diaphragm: in the second case it was not possible to do a fluoroscopic examination. The lessons to be learned from these two cases are that cases of tubal stenosis should be treated with especial care and that they should not be subjected to a prolonged insufflation. The volume of gas used should not be more than 50 to 75 c.c., and the amount should be rigidly controlled. The appearance of any unusual symptoms during the test should indicate the immediate cessation of gas insufflation.

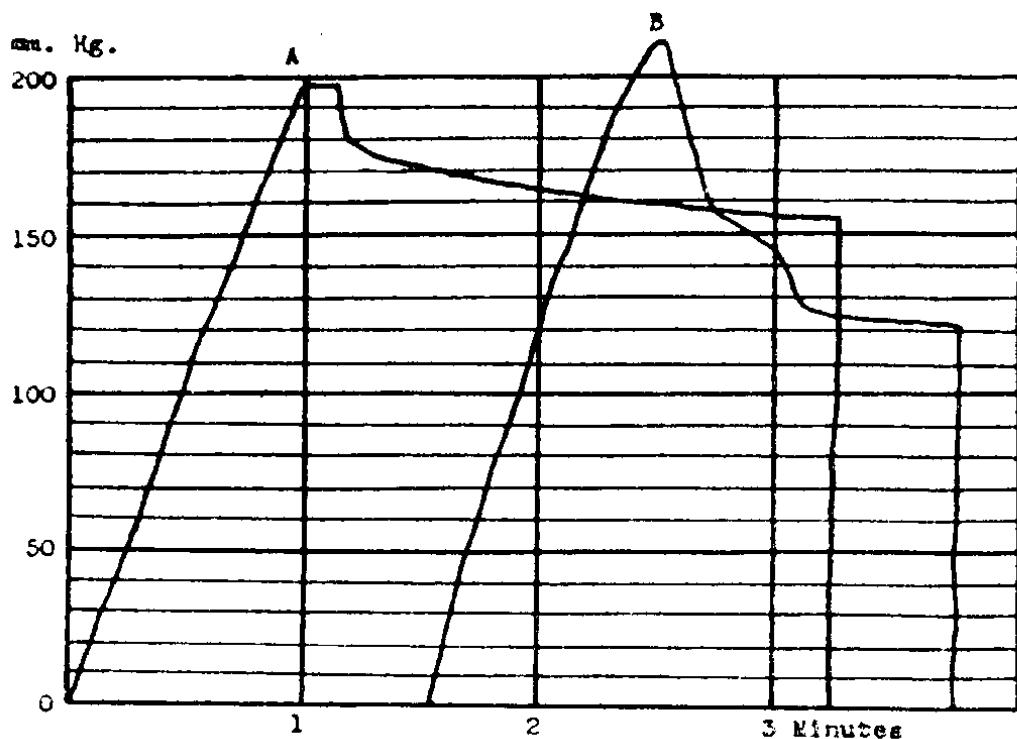
THE THERAPEUTIC VALUE OF UTERO-TUBAL INSUFFLATION.

It has long been recognised that tubal insufflation has a value altogether distinct from the diagnostic one. This was first realised when it was found that a relatively large proportion of sterile patients became pregnant after undergoing tubal insufflation. This, however, is not the only way in which the test may be said to have a therapeutic action. The therapeutic effect may be seen in the following ways:—

(a) *Establishment of a greater or more normal degree of tubal patency in cases previously showing signs of partial obstruction.*

This effect is seen not infrequently and is tantamount to a dilating action on the tubal stenosis or strictures during the course of successive insufflations. In Fig. No. 15 an immediate dilating effect is seen. In the first curve gas is stopped at A and, after a short pause, commences to pass slowly, the curve indicating a high degree of stenosis. A second insufflation carried out immediately after the first, in which gas injection was stopped at B, shows a definitely greater degree of permeability. This is the type of case which might benefit from monthly repetition of the test on the 8th or 10th day of the menstrual cycle. In

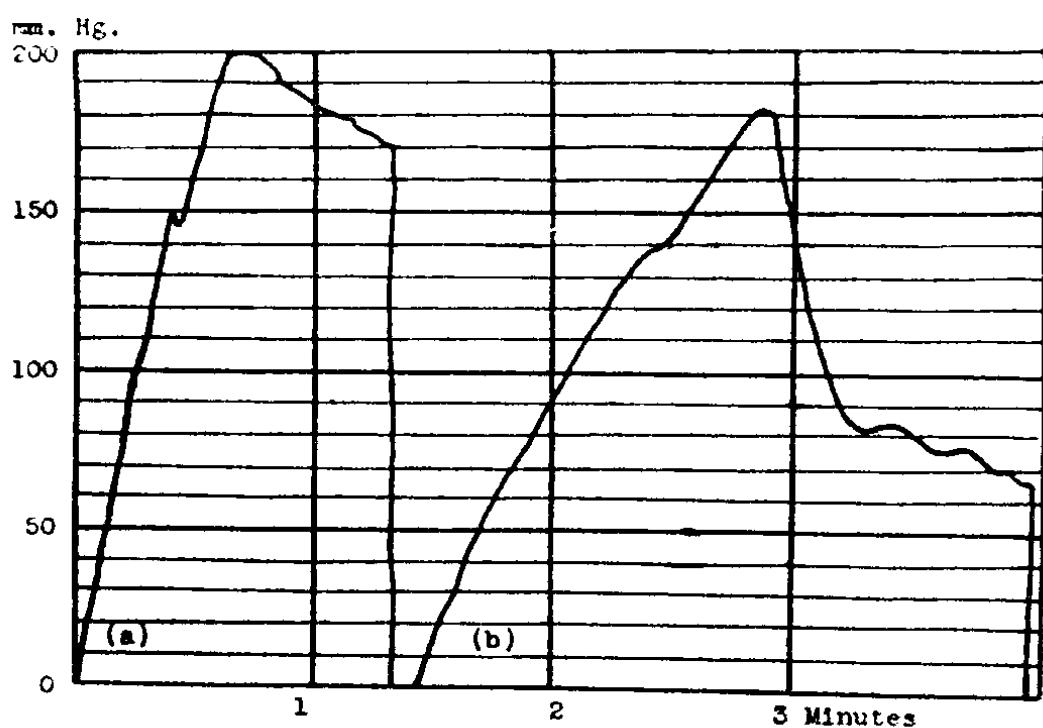
Fig. 15.



Tubal stenosis, showing the dilating effect of a repeat insufflation.

- (a) Shows a high grade stenosis which yields under pressure. Injection of the gas is stopped at the point A.
- (b) Shows the result of a second insufflation carried out immediately after the first. Injection is stopped at the point B, but a greater degree of permeability is seen. (Case No. 532).

Fig. 16.



Tubal stenosis, showing therapeutic value of repeated insufflation.

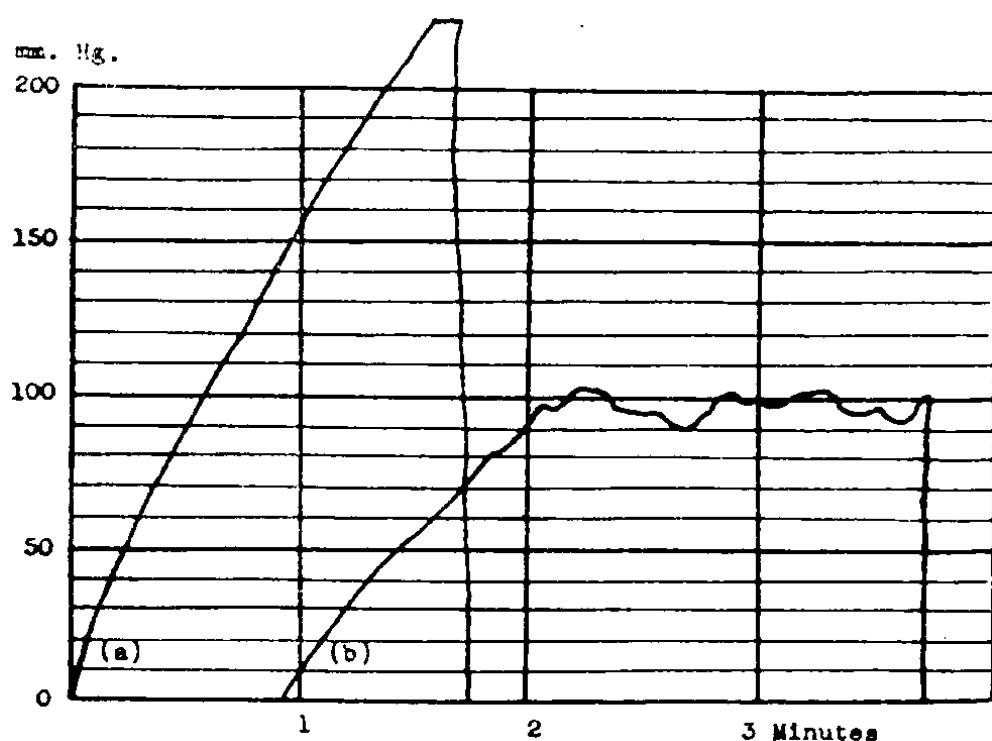
- (a) Shows the result of the first insufflation.
- (b) Shows the result obtained four months later, after monthly repetition of the test. (Case No. 508).

Fig. No. 16 a similar case is shown in which the first examination, (a) demonstrates a high grade tubal stenosis. Insufflation was repeated at monthly intervals with gradual improvement, and four months later the second graph (b) was obtained. This still shows a degree of stenosis, with an initial pressure of 180 mm. Hg. : but the pressure falls to 65 mm. at the end of the test, whilst gas is still passing, and three faintly marked waves of tubal peristalsis can be observed.

(b) *Re-establishment of patency in cases previously showing complete occlusion.*

The failure of gas to pass may be due to inspissated mucus blocking the tube lumen, kinks of the tube wall, pressure on the tube from without, adhesions involving the fimbriated extremity, or obliteration of the tube lumen at some point or points as a result of inflammatory disease. Certain of these conditions are at times amenable to the use of insufflation. A plug of

Fig. 17.



Therapeutic effect of repetition of insufflation in a case of secondary sterility with retroversion of uterus.

(a) Shows complete tubal obstruction.

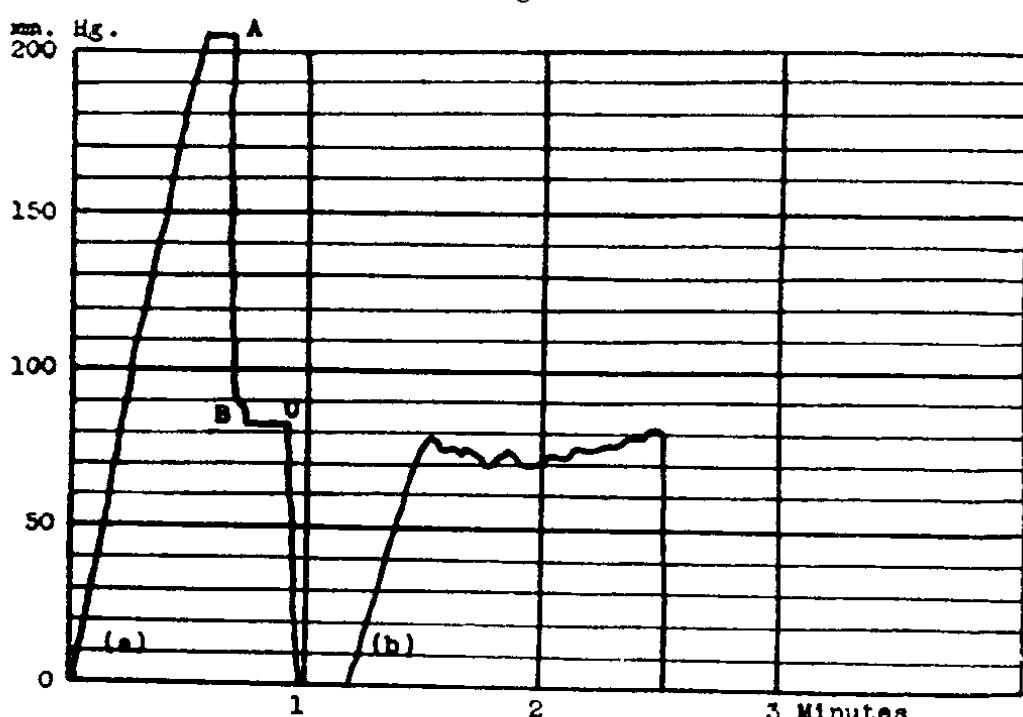
(b) Shows tubal patency on repetition of the test one month later.

(Case No. 262).

secretion may be expelled or displaced, a kink may be straightened out, outside pressure may be overcome or light adhesions may be broken down. In cases with retroversion of the uterus kinking of the tube is not infrequently present and may be a cause of sterility. Fig. No. 17 shows such a case where complete

obstruction was present at the first examination, with normal patency one month later after an attempt at replacement of the uterus. An example of the type of graph seen when there is a breaking down of adhesions surrounding the fimbriated extremity is shown in Fig. No. 18. The first insufflation shows complete obstruction at a pressure of 205 mm. Hg. until the point A is reached, when there is a sudden descent of the pressure to B, accompanied by some definitely painful sensations in the pelvis.

Fig. 18.



Graph showing the breaking down of tubal obstruction, probably due to adhesions.

- (a) Shows tubal obstruction which is overcome at the point A. The pressure falls to B, at which point it remains until released at C.
- (b) This curve was obtained a few minutes later and shows normal patency with some tubal contractions. (Case No. 491).

Repetition of the test a few minutes later shows normal patency with some tubal contractions. In this case it is almost certain that some light adhesions around the abdominal ostium of the tube were broken down. The sudden pain with rapid descent of the pressure indicated this. In the absence of pain a similar graph might have been produced by the relaxation of tubal spasm. In cases of spasm, however, no pain is complained of.

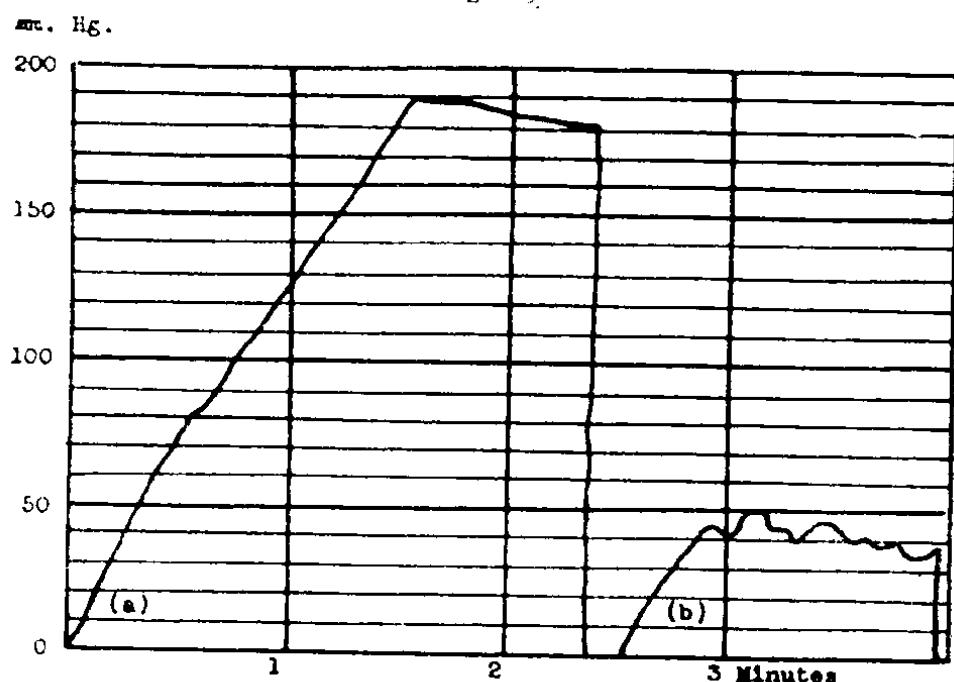
- (c) *To demonstrate and maintain patency during and after certain operative procedures.*

During operations for the restoration of the tube lumen insufflation plays an important part. A cannula may be placed

in position before the operation is commenced and patency demonstrated by carrying out insufflation whilst the abdomen is open and during the process of freeing the tubes. Another method is to insufflate from above by means of a fine cannula attached to a syringe and inserted into the fimbriated extremity of the tube. After such operations tubal insufflation should be repeated at stated intervals and plays an important part in maintaining the newly established patency.

In Fig. No. 19 curves are shown which were obtained before and after an operation for ventral suspension of a fixed and retroverted uterus. Preliminary insufflation showed tubal obstruction, or possibly a high grade stenosis. At operation numerous adhesions were present in addition to kinking of the tubes. The adhesions were separated, tubal patency was established and the uterus was suspended by a round ligament operation. Repetition of the test a couple of weeks later showed a perfectly normal patency curve.

Fig. 19.



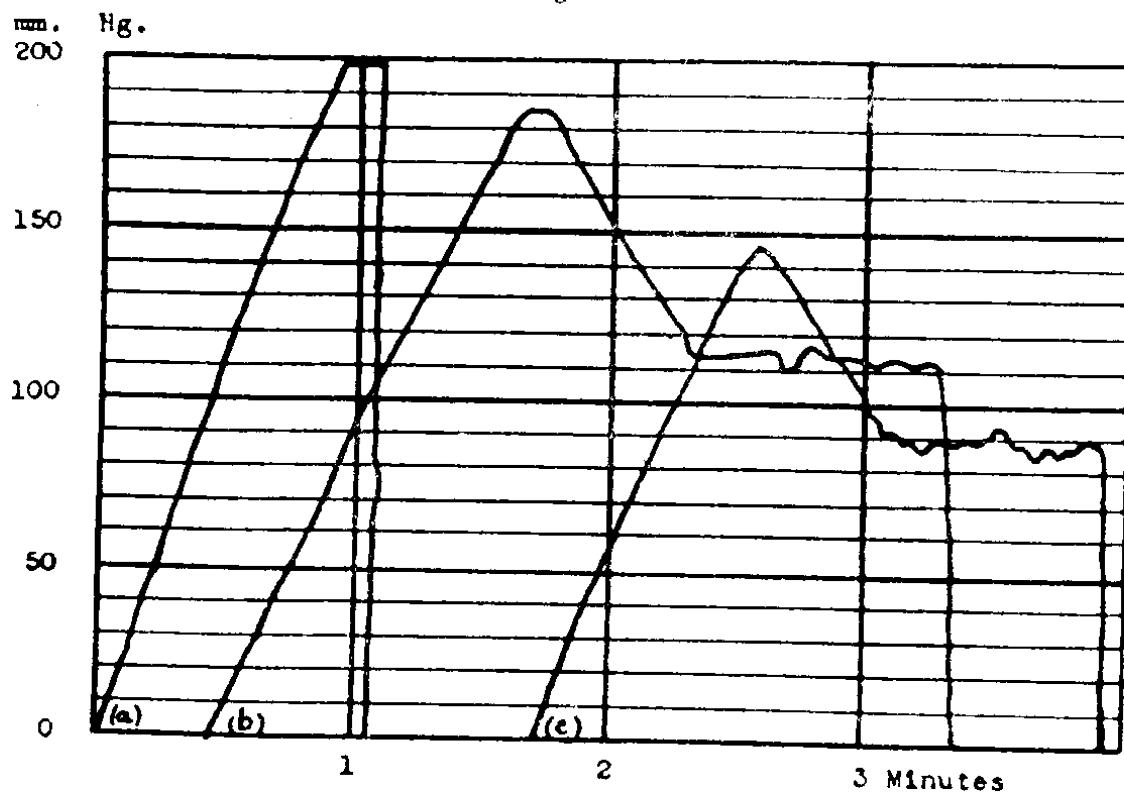
Graphs showing the results of insufflation performed before and after ventral suspension of a fixed and retroverted uterus.

- (a) Preliminary insufflation shows tubal obstruction, or possibly a high grade stenosis.
- (b) Shows normal tubal patency after suspension of the uterus and separation of numerous adhesions. (Case No. 588)

Tubal insufflation is an essential part of the after-treatment in cases of salpingostomy or utero-tubal implantation. Meaker (12) has advised the routine performance of insufflation in all such cases at intervals of one, three and six weeks after the

operation, and it is the practice of the writer to follow this procedure. Altogether a series of 12 salpingostomies has been performed, with resulting normal patency in 6 cases, tubal stenosis in 4 cases and failure to restore permanent patency in 2 cases. In Fig. No. 20 graphs are reproduced from a case in which salpingostomy was performed. The first graph shows the condition before operation, the second shows that patency was maintained 9 months later and the third graph, obtained 14 months after the original operation shows satisfactory tubal patency. Gas was heard to pass through both tubes during the insufflation, right shoulder pain developed after the test and a well marked pneumo-peritoneum developed under each dome of the diaphragm.

Fig. 20.



Bilateral salpingostomy:

Curve (a) shows complete non-patency before operation: Curve (b) shows patency maintained 9 months after salpingostomy and curve (c) shows the result 14 months after operation. (Case No. 235).

Another procedure in which insufflation plays an important part in the after treatment is after an operation for extra-uterine gestation. Rubin (13) has made a special study of this question and has shown that in a large series of cases only 12.35% of patients operated on for tubal pregnancy showed normal patency of the residual tube. This is largely due to the fact that the residual tube becomes involved in adhesions, and therefore functionless, even though intrinsically it may be a perfectly sound tube. In those cases, therefore, where the residual

tube is seen at operation to be healthy and patent, post-operative insufflation will assist in preserving the patency of the lumen and with it the patient's chance of a future pregnancy.

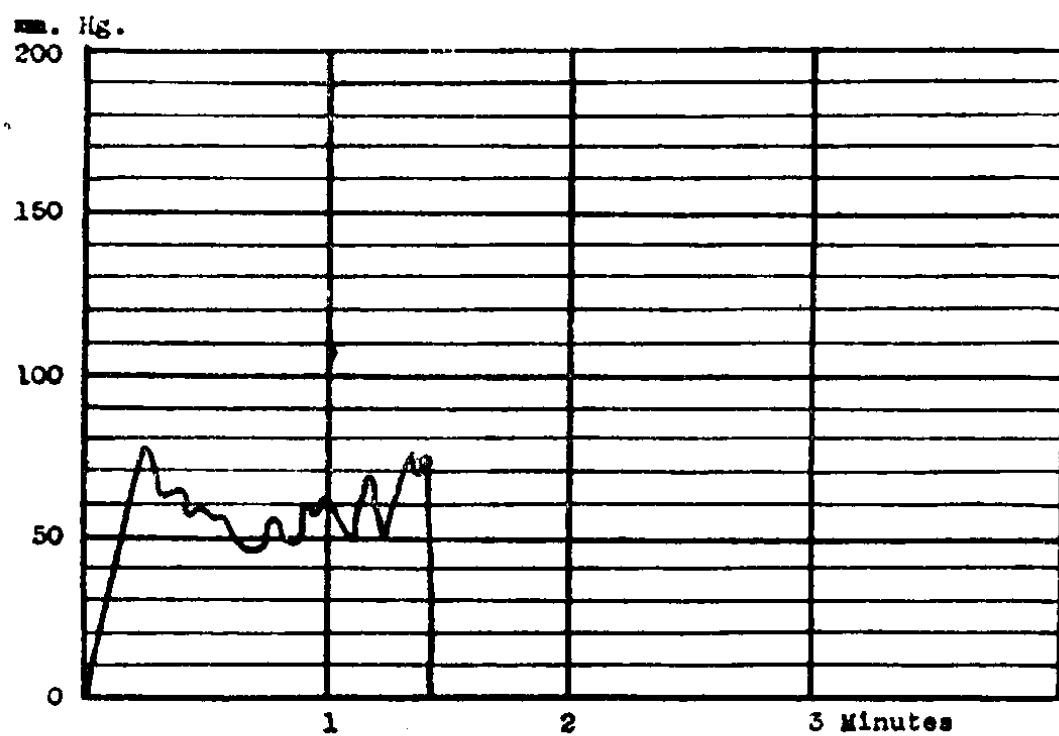
(d) *Relief of Dysmenorrhoea.*

It has been noted by several observers, of whom the first were Peterson and Cron (14), that a marked relief of dysmenorrhoea follows the performance of tubal insufflation in many cases. In the present series no complete follow-up examination has been possible, but in 300 cases which were followed there was an improvement of dysmenorrhoea reported in 38, a sufficiently large number for the writer to be able to confirm the observation originally made by Peterson and Cron.

(e) *The occurrence of Pregnancy following Utero-tubal Insufflation.*

To the patient the ultimate criterion of the successful treatment of her condition is the occurrence of pregnancy. When

Fig. 21.



Pregnancy following tubal insufflation. The above curve was obtained on the 12th day of the menstrual cycle in a case where no pregnancy had occurred within two years of marriage. The patient had no further period and was delivered at term of a healthy child. (Case No. 498).

uterotubal insufflation was first performed there was no thought that it possessed anything more than a diagnostic value. In 1923, however, Peterson and Cron (14) pointed out that in a

number of cases pregnancy followed the employment of insufflation without the use of any other measures. In 1929 Rubin (15) reported that insufflation was followed by pregnancy in 205 cases out of a series of 2,000 cases of infertility. In August 1937 the number of pregnancies collected personally by Rubin had increased to 519 (a figure quoted by Bonnet (16) in his excellent monograph on Kymographic Insufflation). Rubin found, on analysis, that pregnancy occurred in 17.5% of all his cases insufflated for sterility, and in nearly half of these cases the pregnancy took place within two months of the insufflation. These observations have been confirmed by many other writers, and the relationship of insufflation to a subsequent pregnancy is certainly proved to be more than a matter of chance occurrence. Bonnet (16) for example, reports 18.4% of pregnancies in his series of insufflations. In my own personal series I have observed 22 definite cases of pregnancy following insufflations, of which 11 occurred within 2 months. The difficulties of follow-up work have been very great in China during the last three years of war, and there are undoubtedly other cases in the series in whom pregnancy has occurred without any report being made. In an earlier group of 272 patients which was carefully followed it was found that 6% became pregnant. If only those patients found to have patent tubes were taken into account, it was found that 11.6% subsequently became pregnant. The average duration of the childless marriage in these cases was 5½ years, and all but two cases were suffering from primary sterility. Fig. No. 21 shows a graph obtained in a recent case where no pregnancy had occurred after two years of marriage. The insufflation was performed on the 12th day of the menstrual cycle, just before the probable date of ovulation. The patient had no further period and was delivered at term of a healthy child.

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MANGANESE POISONING: TWO CASE REPORTS,

by

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INTRODUCTION.

Considering the frequency with which Chinese of the working classes are exposed to direct contact with manganese salts in Hong Kong, it is striking that cases of manganese poisoning should be so rare. As far as can be ascertained there are no records of previous cases of manganese poisoning in the Colony, a fact which makes these two cases noteworthy.

The factory in which these two men worked was visited to see how close their contact with manganese ore had actually been. The place was a processing plant rather than a factory and its main function was to reduce the crude ore to a powder which could be used in the manufacture of batteries. The crude ore which is mined in Kwangsi reaches Hong Kong in the form of irregular lumps each about the size of a grapefruit. These lumps are first of all washed in tubs of water and then broken up by hand into small fragments which are fed into grinders housed in a special room. This room which is about $40' \times 25'$ is adequately ventilated by windows, and some effort is made to reduce the amount of free dust in the air by covering the containers which receive the powder with bags of sack-cloth. The men in the grinding room work a nine-hour day during which the exposed parts of their bodies are completely blackened by the fine powder produced by the grinders. The grinders were not seen working but everyone admitted that the room was full of dust when they were, a statement supported by the finding of early pneumoconiosis changes in the second patient. Of the five men who managed the grinders one had been employed in the grinding shed for two and a half years, the others for about one year and they all said they were in perfect health.

A specimen of the powder showed the following results on analysis:—

The sample is pyrolusite, such as is used in battery manufacture. It contains 71.6% of manganese dioxide (MnO_2), together with iron and water of combination, also a little absorbed moisture, silica and organic matter.

CASE HISTORIES.

CASE I.—L.W.W. a Chinese male aged 25 came to Out-patients on June 17 this year complaining that for the last three months his legs had been growing weaker and his gait had been unsteady. He also complained of occasional tremor in the legs. The arms and hands had become weak and tremulous one month ago, the tremor being more marked apparently on innervation.

For one month past he had complained of "hoarseness." Salivation had been marked and troublesome throughout the whole of this illness, but he had not experienced any sensations of heat nor had sweating been excessive.

His appetite was good and he complained of no gastric disturbance or constipation. He slept well and had suffered no loss of weight. There had been marked loss of libido and potency for the last 8 months. He stated that he had been working in a manganese factory for one year and that his job was to handle the manganese itself. His face, arms and hands were continuously exposed to the manganese ore during his nine-hour working day and at the end of a day's work were quite black.

Previous History.

He had had malaria 3 years ago, but there was nothing else significant in his past history. There was no nervous disease in the family. He was admitted to hospital for investigation.

Physical Examination.

The man was a well nourished, well built Chinese whose stance was slightly Parkinsonian. His face was expressionless and mask-like and he tended to sit with his hands on his thighs in the interosseal attitude. Voluntary facial movement was slowed. No emotional change or abnormality of behaviour was noted.

Nervous System. Attention was fair but the man's reaction time seemed slower than normal. Articulation was a little slurred and the voice was low and monotonous. Pupils reacted to light and on convergence and there was no defect of ocular movement. The tongue was wet and tremulous and on innervation of the face fine circumoral and palpebral tremor was apparent. The fundi, optic discs, visual fields and tympana were normal.

Gait. He walked on rather a wide base, and his gait was a little "sticky." He was clumsy and tended to sway in turning, and it was noted that the great toe on both sides tended to be cocked up as he walked. There was no Rombergism, propulsion, retropulsion or lateripulsion. The automatic movements of his arms in walking were diminished.

Motor System. Both arms and legs showed a slight excess of extensor tonus. Tremor was obvious in the outstretched fingers of both hands and occasional tremor was noted in the feet. The tremor was fine and inconstant, and was occasionally noted in the hands and fingers when the patient was at rest. Emotion tended to increase this tremor at rest. Motor power was diminished at all joints in both legs, but no definite loss could be made out in the arms. There was no incoordination or dysdiadochokinesia, nor was any atrophy made out. Fibrillation was not noted.

Sensory System. No evidence of impairment to any form of testing could be detected.

All the tendon reflexes were brisker than normal, but no ankle clonus was elicited and both plantar responses were flexor. There had been no sphincter disturbances.

His lungs, heart and belly were normal. Neither liver nor spleen was palpable and the urine contained no sugar and no albumen.

Attempts were made to demonstrate the presence of manganese in the urine and faeces. Significant amounts were not found in the urine, but the faeces contained 1.7 mgm. of manganese per 100 gm.

His blood picture was as follows:—

Haemoglobin	14 gms. %
Red blood corpuscles	4,670,000 per cu. mm.
White blood corpuscles	6,600 per cu. mm.
Polymorphonuclears	63 %.
Lymphocytes	32 %.
Large mononuclears	3 %.
Eosinophils	2 %.

No hypochromia. No malarial parasites. The blood fragility was within normal limits. His cerebrospinal fluid was clear and colourless and manometric readings were normal. It contained a trace of globulin and 4 cells per cu. mm. The sugar content was 68 mgm. %, the chlorides 691 mgm. %. The blood urea was 28 mgm. %, and the blood pyruvic acid was 1.3 mgm. %. The Kahn test both in blood and cerebrospinal fluid was negative.

An X-ray of the chest revealed no definite evidence of pneumoconiosis, but the left apex was thought to be suspicious of tuberculosis. The laevulose tolerance test indicated a definite degree of hepatic dysfunction, the figures obtained at half hourly intervals after 40 gms. of laevulose had been given by mouth being:—

Fasting blood sugar	76	mgm. per 100 c.c.
½ hour	90
1 hour	99
1½ hour	101
2 hour	148
2½ hour	134
3 hour	88

The urine was examined for urobilin and urobilinogen with negative results, but the van den Bergh reaction gave a faint indirect positive. The icterus index was 2.

A fractional test meal demonstrated the presence of a normal amount of free hydrochloric acid in the gastric juice.

CASE II.—C.C., an unmarried Chinese male of 30 came to Out-patients on June 24th complaining that during the last month his legs had become weak, his arms tremulous and his voice hoarse. He had also had some flatulent dyspepsia and cough during the last two weeks.

His main complaints were that in walking his feet tended to stick to the ground and his hands were so shaky that he could only use chopsticks with difficulty. Both his arms and his legs were weak and coupled with this was a general weakness which made him unable to carry heavy loads. Salivation was marked at the onset of the illness but disappeared within a week or so. He had had two attacks of cramp and twitching in the muscles of the right calf in the early stages of the disease, and he also volunteered the information that his memory had become impaired since his illness began.

He complained of no anorexia, no disturbance of sleep and no loss of weight but there had been some loss of libido and potency during the past few months. His general appearance was well nourished.

He said he worked in the same factory as the first patient, grinding manganese ore into powder, and he had been working there for one year. He said the ventilation of the building was poor and that he breathed in a lot of dust.

Previous History.

He had had malaria 8 months ago but there was nothing else noteworthy in his past history. There was no family history of nervous disease.

Physical Examination.

The patient was a well built stocky man with a slightly Parkinsonian mask. His stance was also Parkinsonian. In conversation the normal play of facial expression was completely lost, his voice was low and monotonous and his speech tended to be slurred. There was a definite loss of emotional control. The man frequently laughed for no apparent reason and his manner was unquestionably facile.

Nervous System. Attention was fair but the man's reaction time was slow and his memory was very poor. The pupils were equal and regular in outline and reacted normally to light and on convergence. There was no nystagmus, diplopia, strabismus or limitation of ocular movement. The tongue was wet and tremulous and on innervation of the facial musculature fine tremor was noted in the circumoral and circumpalpebral muscles. The optic discs, tympana and cranial nerves were normal.

Gait. There was a slight tendency to Rombergism. On walking the man's gait was "sticky," he was clumsy and swayed in turning. There was some diminution of normal arm swinging, and retropulsion could be elicited but neither propulsion nor lateripulsion were demonstrable.

Motor System. There was generalised slight hypertonus. There was also slight loss of motor power at all joints in both arms and legs, but no atrophy, inco-ordination or dysdiadochokinesis. Tremor was fine and inconstant and was best elicited on innervation of the facial or arm muscles. The cogwheel phenomenon could be elicited by passive flexion and extension of the elbow joint. It lessened if these movements were repeated many times, only to reappear after a few moments rest. Tremor was occasionally noted in the fingers when the patient was completely at rest.

Sensory System. No evidence of sensory impairment could be detected on testing with cotton wool, pin prick, tuning fork or hot and cold tubes. There was no loss of joint sense or sense of position in space.

The knee and ankle jerks were absent but the arm jerks were present on both sides. No clonus was elicited and the plantar responses were flexor. The abdominal reflexes were normal and there had been no sphincter disturbances.

The lungs and heart were normal on clinical examination and neither liver nor spleen was palpable. The skiagram of chest showed a slight enlargement of heart and aorta and lung changes suggestive of early pneumoconiosis. The urine contained no sugar, no albumen and no urobilin or urobilinogen. No casts or cells were found in the urinary deposit. The faeces contained ova of trichuris and ascaris and gave a positive reaction for occult blood.

Efforts to demonstrate the presence of manganese in the urine and faeces gave negative results for the urine but showed 3.1 mgm. of manganese per 100 gm. of faeces.

The blood picture was as follows:—

Haemoglobin	14.6 gms. %.
Red blood corpuscles	5,310,000 per cu. mm.
White blood corpuscles	5,040 per cu. mm.
Polymorphonuclears	54%.
Lymphocytes	38%.
Large mononuclears	2%.
Basophils	4%.
Eosinophils	2%.

The blood films were not hypochromic and no malarial parasites were found. Corpuscular fragility was normal.

The blood urea was 16 mg. per 100 c.c., and the blood pyruvic acid was 1.5 mgm. per 100 c.c.

The cerebrospinal fluid showed no naked eye abnormalities. It contained 8 cells per cu. mm. and the chlorides were 742 mgm. per 100 c.c. Queckenstedt's phenomenon was normal on both sides and the fluid and blood Kahn tests were negative. The laevulose tolerance test indicated a mild degree of hepatic defect, the figures before and after 40 gm. of laevulose by mouth being:—

Fasting blood sugar	79.5	mgm. per 100 c.c.
½ hour	144.5
1 hour	123.5
1½ hours	122.5
2 hours	91.5
2½ hours	87.5
3 hours	80.5

The van den Bergh reaction gave a faint positive indirect reaction and the icterus index was 2. A fractional test meal showed that the gastric juice contained a normal amount of free hydrochloric acid.

DISCUSSION.

The picture presented by these two patients is characteristic of early manganese poisoning. Both of them complained of a loss of physical and mental energy accompanied by slight generalised rigidity, a peculiar gait, tremor, salivation and voice changes. Both showed a Parkinsonian mask when their faces were at rest, all expression being lost. There was a look of mournful expectancy about them and although the facial musculature responded well to voluntary innervation the normal play of expression in conversation was completely lost. Speech in both cases was soft and monotonous. Staccato elements were conspicuously absent nor was there any tendency to palilalia or explosive outbursts. The tremors complained of by both these patients were best seen when some voluntary effort was made such as moving a limb or maintaining it in a given posture, but they were also occasionally noted when the patients were at rest, and Case I frequently displayed a classical pill rolling tremor when at rest in bed. This tremor was increased by emotion or excitement. Both men said that the tremor varied much from time to time.

Hypertonus was present in both patients and in Case II was sufficiently marked to give rise to the "cogwheel" phenomenon on passive flexion and extension of the elbow joint. This resistance passed off if the movements were repeated many times but reappeared after a few moments of rest. The plantar and abdominal reflexes were normal, an indication that the lesion had affected the extrapyramidal system only. No trace of myotonia was noted in either case nor was it possible to determine with certainty whether emotional control had been impaired. Both patients gave the impression that mentation was definitely slowed and one appeared to be definitely euphoric in ordinary conversation.

One of the most interesting features of this toxæmia is that manganese is the only toxic agent known to produce disease both of the liver and the nervous system. There are numerous cases of chronic manganese poisoning on record which showed both cirrhosis of the liver and nervous signs suggestive of lenticular involvement. Findlay (1924) showed that manganese chloride injected repeatedly in small doses into rabbits produced a picture characterised by lassitude,

anorexia, weight loss and an icteric tingeing of the tissues. Autopsy showed mild cirrhosis of the liver. Mella (1924) was able to produce an extrapyramidal syndrome characterised by athetosis and generalised rigidity by intraperitoneal injections of the same salt in monkeys, and autopsy showed a gliosis particularly marked in the lenticular nucleus.

The recorded cases of industrial poisoning with manganese dioxide correspond closely with the picture presented by these two men; all showed a condition resembling *paralysis agitans* marked by tremors, rigidity, voice changes, salivation and a mask-like facies. That is to say, the clinical signs of manganese poisoning are evidently due to involvement of the extrapyramidal system, but precisely what portion of the system is obscure. One is naturally impelled to draw an analogy between this condition where a known toxic agent involves both liver and basal ganglia, and Wilson's disease or hepato-lenticular degeneration. The absence of dysarthria and dysphagia, the presence of a Parkinsonian mask and the soft monotonous voice seem to point clearly to the fact that manganese does not affect the putamen solely.

The clinical picture presented by these two cases resembles rather that seen in Parkinson's disease and post-encephalitic Parkinsonism than in hepato-lenticular degeneration. It would seem, therefore, that the main incidence of the nervous lesion in manganese poisoning is on the cells of the globus pallidus and on the ansa lenticularis.

But despite the fact that it is impossible to place their lesion more precisely than this, both these patients showed the combination of hepatic defect with an extra-pyramidal syndrome.

Another point of clinical resemblance between hepato-lenticular degeneration and manganese toxæmia is that in both conditions the manifestations of the cirrhosis during life may be very slight.

Barnes and Hurst (1925) have described four cases of hepato-lenticular degeneration in one family, with autopsies on three of the cases, and they stressed the point that the nervous symptoms do not appear until the liver has become markedly affected. Unfortunately it was impossible to demonstrate the liver defect during life in all these cases, but their series supports the view that in hepato-lenticular degeneration a toxin is elaborated intermittently as a result of recurring attacks of hepatitis and that this toxin exerts a selective action on the lenticular nucleus. Whether the toxin be alimentary or hepatic in origin is as yet an unsettled point.

Charles (1927) suggested that liver feeding might benefit cases of manganese poisoning by supplying a deficiency of a hormone acting on certain parts of the brain, and he recorded one early case of the toxæmia which derived great improvement from liver feeding. The

results in later cases were disappointing and this may be because the affected nerve cells had been destroyed before treatment was begun.

The absence of the knee and ankle jerks in the second patient is almost certainly to be attributed to an avitaminosis B₁. It is common in Hong Kong to find loss of these reflexes in people who have never had frank beri-beri or any symptoms suggesting it. They are the people who live on the pre-beriberic level and they are apt to develop the disease in an acute and unmistakable form if they succumb to an intercurrent infection.

It is to be noted that the blood pyruvic acid level in both these patients was above the normal level of 0.7 mgm.%, and although a blood pyruvic acid of 1.5 mgm.% undoubtedly supports the suggestion of an avitaminosis B₁ in the second patient, it is noteworthy that the first patient whose blood pyruvic acid was 1.3 mgm.% showed no signs whatever of beri-beri. It may be that the persistent mild hypertonus had helped to produce the excess in both cases by causing an increased breakdown of muscle substance.

Both these men were treated with liver extract given intramuscularly, the first one receiving 34 c.c. of livamine, the second 36 c.c. Neither of them showed the slightest response to this form of therapy and on discharge their Parkinsonism was precisely what it had been on admission.

SUMMARY.

1. Two cases of manganese poisoning are described.
2. Evidence is adduced to show that they were probably poisoned by inhaling manganese dioxide at their work.
3. Liver extract appeared to be of no value in treatment though both patients showed a hepatic defect.
4. The available literature is briefly reviewed.

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A HEART SHOWING MULTIPLE ERRORS OF DEVELOPMENT,

by

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(1) Introduction	(5) Embryological notes.
(2) External Features.	(6) Summary.
(3) Dissection.	(7) Acknowledgements.
(4) The Mechanism of the Heart.	

I. INTRODUCTION.

The following notes concern the heart of a male child of approximately two years that came to autopsy at the Victoria Mortuary, Hong Kong, during April 1940. The cause of death was found to be broncho-pneumonia.

Some gross abnormality of the heart was detected before the heart had been extensively dissected. For permission to take the specimen and examine it in more detail we are indebted to Dr. Alvares.

Congenital defects of the heart are not uncommon, but it must be unusual indeed to meet so many abnormalities in one specimen.

Imperfect septa between the atria or between the ventricles and patent ductus arteriosus are frequently met. All these are present in this case and in addition, occlusion of the mitral orifice and patent foramen ovale.

It becomes a matter of some interest to speculate upon the mechanism of the circulation of the blood and the probable effects of the abnormalities upon the economy of the patient.

An abnormality which caused us some perplexity is one that can have had but little physiological influence upon the circulation. This was the presence in part of a left superior vena cava.

In the normal course of development the potential left superior vena cava atrophies and leaves relics in the coronary sinus of the heart and a variable vein which may connect the coronary sinus to the left innominate vein or one of its tributaries. This vein, when present, is called the "oblique vein" of the left atrium, or of Marshall. In this case the coronary sinus and the oblique vein are both very well developed.

It was the size and the position of the oblique vein that caused difficulty, until its true nature was appreciated, because it was so large and so placed as to isolate the left atrium within the cavity of the heart and to produce a very unusual arrangement.

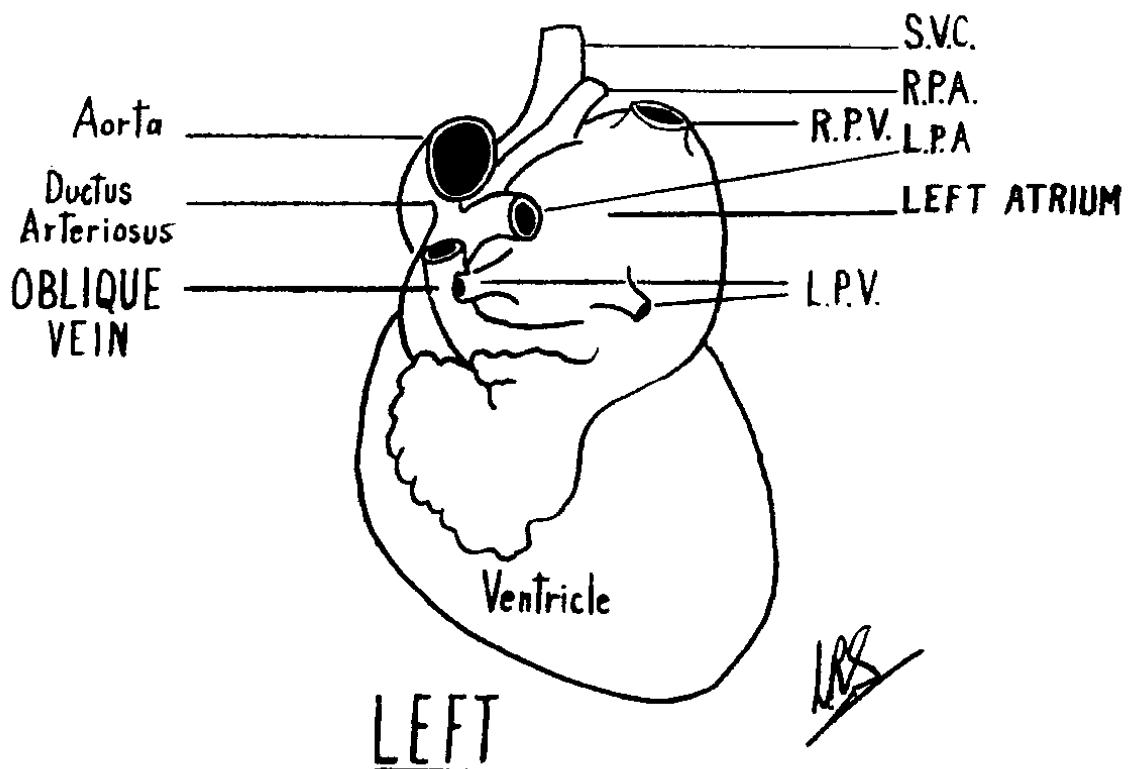
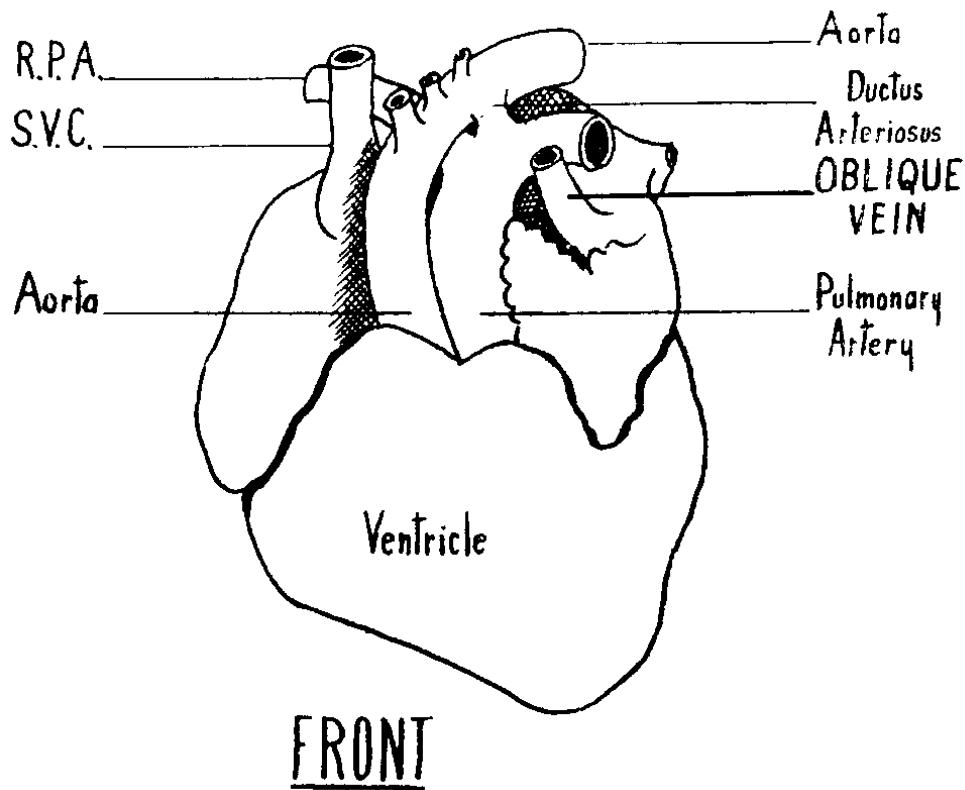


Fig: 1.

This figure presents drawings of the heart in outline as seen from the front and from the left side. The reader should note the positions of the aorta, the pulmonary artery and of the oblique vein.

S.V.C. = superior vena cava; R.P.A. and L.P.A. = right and left pulmonary artery respectively; R.P.V. and L.P.V. = right and left pulmonary vein respectively.

Unfortunately the great vessels had been cut rather close to the heart and only the stump of the oblique vein was left. However, we have no doubt as to its identity.

Descriptions of the heart with its various imperfections follow together with speculations on the mechanism of the circulation and some embryological notes.

II. EXTERNAL FEATURES.

Figure I. shows the external features of the heart in a diagrammatic fashion as seen both from the front and from the side.

From the front there is no obvious separation into right and left ventricles, usually indicated by an interventricular groove. The expectation of finding a single undivided ventricle was fulfilled at the first incision in the Mortuary.

The aorta and the pulmonary artery lie in almost the same transverse plane side by side. A large ductus arteriosus connects the left pulmonary artery to the arch of the aorta at a point just distal to the left subclavian artery.

From the left extremity of the left atrium proper, at the base of the left atrial appendix, arises the vein which is variously called the "oblique vein of the left atrium" or the "oblique vein of Marshall." This vein has an upward course anterior to the lower left pulmonary veins and the left pulmonary artery. These features are perhaps best shown in Fig: I. in the view from the left.

In size this vessel is comparable with the innominate artery but is smaller than the superior vena cava or the left pulmonary artery. It opens into the left atrium.

From the back there is no inter-atrial groove and the size and position of the left atrium can only be inferred from the position of the left pulmonary veins. One gets the impression that the left atrium forms but a small part of the atrial portion of the heart.

III. DISSECTION.

The cavities of the heart were carefully packed and the wall sutured before the specimen was hardened in Kaiserling's solution. After hardening the posterior wall was removed piecemeal so as to allow the several cavities to be examined from the back.

The appearances after this procedure are shown in the upper drawing in Fig: II.

The Atria.

The right atrium is roomy, measuring 3 by 2.5 cm. in its main transverse and antero-posterior diameters. It is extended to the left

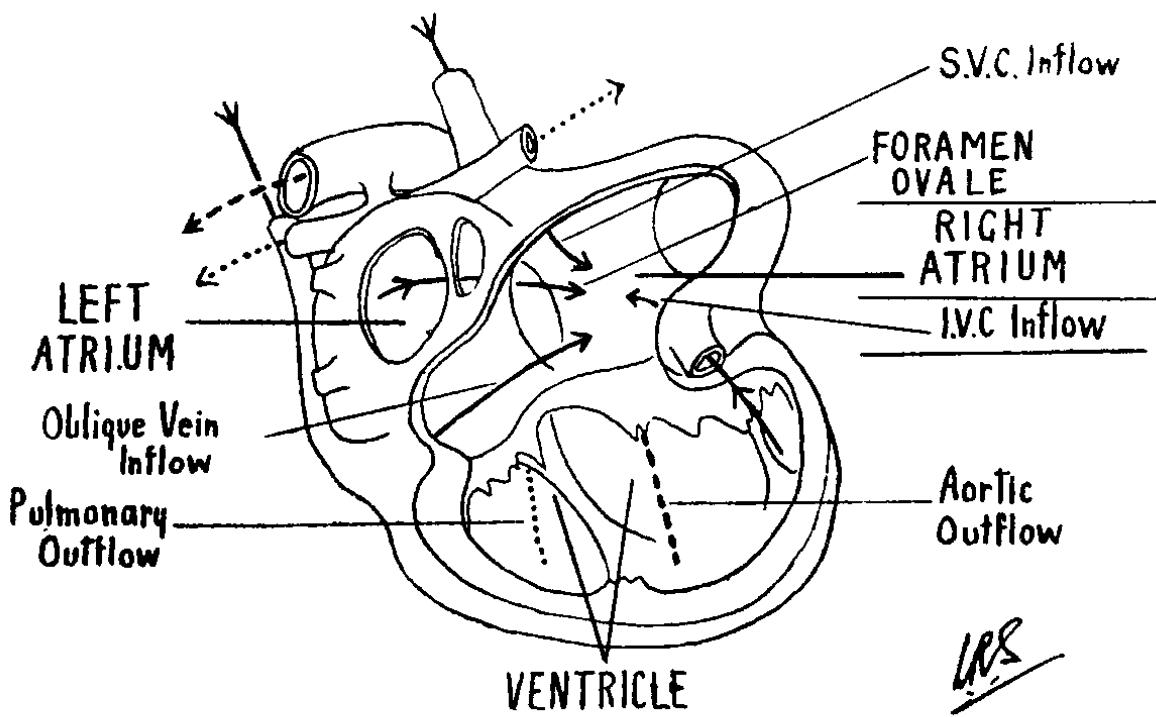
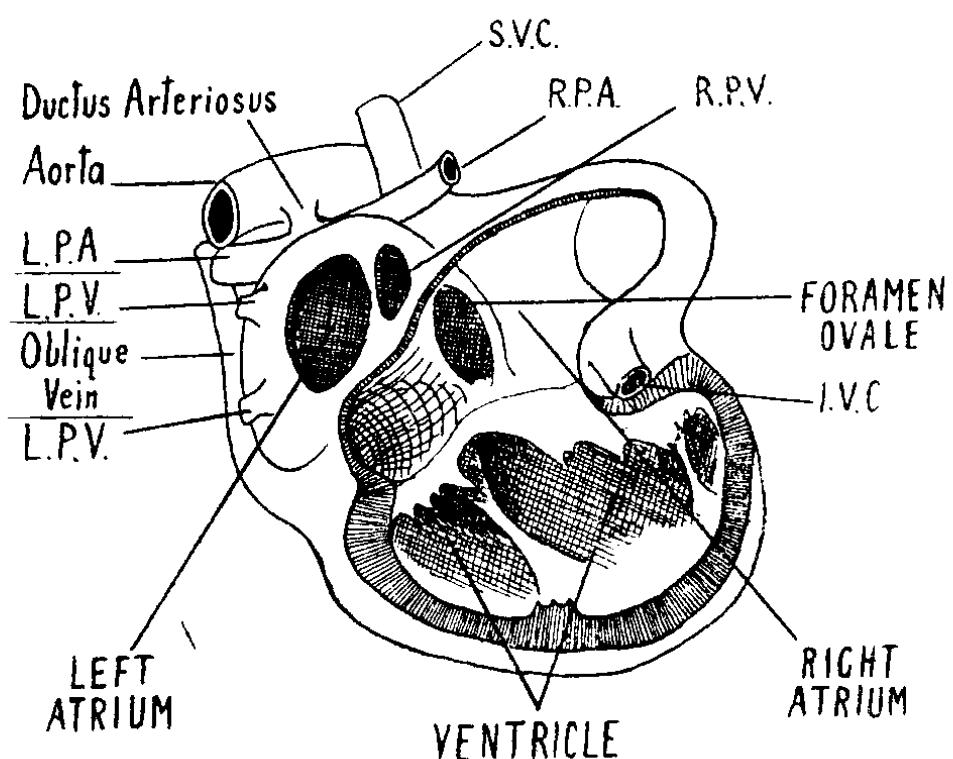


Fig: II.

The upper drawing presents the appearances after a window has been cut in the posterior wall of each chamber of the heart.

The lower drawing shows the same in outline only. It is intended to show the blood flow and the blood content of each of the heart chambers as is explained in the text.

The inflow into the right atrium is shown in heavy black lines which traverse the superior and inferior venae cavae, the oblique vein and the foramen ovale.

A line of dashes — — — and a line of dots . . . show the positions taken up by directors passed through the axis of the aorta and of the pulmonary artery respectively. These lines are indicated as "aortic outflow" and "pulmonary outflow" and are further explained in the text.

by a wide funnel shaped prolongation and between them lies the left atrium.

Where it joins the right atrium the leftward extension is of some 8 mm. diameter. It lies just above the atrio-ventricular groove but below the small chamber of the left atrium.

Fig: II. shows these arrangements. The small left atrium communicates with the right atrium by an orifice in its internal wall. The identification of the small chamber as the left atrium is certain, because it receives the pulmonary veins, notwithstanding any disparity of size or peculiarity of position. The aperture in the inter-atrial septum leading to the right atrium must be a foramen ovale.

If we follow the wide extension of the right atrium to the left we find that it lies at a lower level than the left pulmonary veins; then it follows a course anterior to the bulge of the left atrium and finally it takes an upward turn in front of the left pulmonary artery. In fact this extension of the right atrium is the oblique vein of the atrium.

The lower drawing in Fig: II shows the same outline as the upper drawing but is marked with lines which show the course of the blood stream in the various vessels and heart chambers. It will be clear that the right atrium receives the inflow of the superior and inferior vena cavae on the right, of the oblique vein on the left and of the left atrium through the patent foramen ovale.

The left atrium is a spherical chamber of about 2.5 cm. diameter and much smaller than the right. It receives one pulmonary vein on the right and two on the left side. We may remark here that a reduction of the normal pair of pulmonary veins to a single vessel is not at all an uncommon finding.

The foramen ovale is widely open and is bounded in front and behind by highly muscular margins.

The mitral orifice is occluded.

At the bottom of the left atrium is a small dimple which marks the place where the mitral valve would be expected. There is a translucent membrane here but no opening.

The absence of any direct outlet from the left atrium into any other heart chamber except by way of the foramen ovale is a remarkable finding and has profound consequences upon the circulation.

The Ventricle.

The single ventricle is capacious and communicates with the right atrium through a tricuspid valve which is incompetent. The valve cusps are incompletely separated though they can be recognised.

Fig: II shows that within the cavity of the ventricle is a small papillary muscle near its right wall and a larger muscle bar to the left. This larger bar has its upper attachment just below and behind the foramen ovale and is assumed to be the representative of the interventricular septum. All round this bar there is a clear passage, wider in front and on the right than on the left.

A director passed down the aorta reaches the ventricle on the right of this muscle bar, and if passed down the pulmonary artery appears on the left.

In the lower drawing in Fig: II the director in the aorta is shown by line of dashes — — — and marked "aortic outflow," while that in the pulmonary artery is indicated by a line of dots . . . and the words "pulmonary outflow."

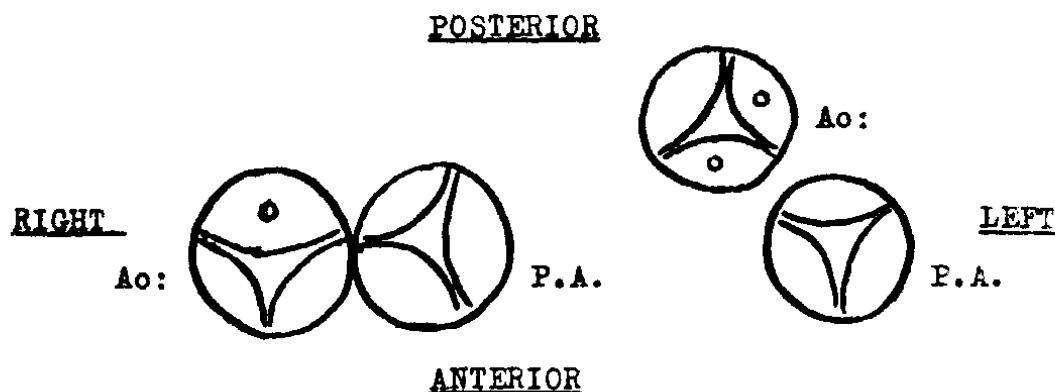
The reader will note that the aortic outflow lies to the right of the pulmonary outflow, though both arise from a common ventricle.

This is a reversal of the common arrangement. The aortic stem usually lies to the left and the pulmonary to the right and anterior to the other.

In this connection it has been noted that the two great trunks lie side by side as they leave the heart (see Fig: I). In the normal the pulmonary trunk lies successively anterior, left and posterior to the aorta, forming something of a spiral. We may infer some congenital defect in the formation of the aortic and pulmonary trunks as well as in the structure of the ventricle.

As might be expected the valves present an abnormal arrangement in correspondence.

The sketch below gives a comparison of the arrangements in this specimen compared with the normal. The plan of the normal lies on the right. The single coronary artery arises as shown.



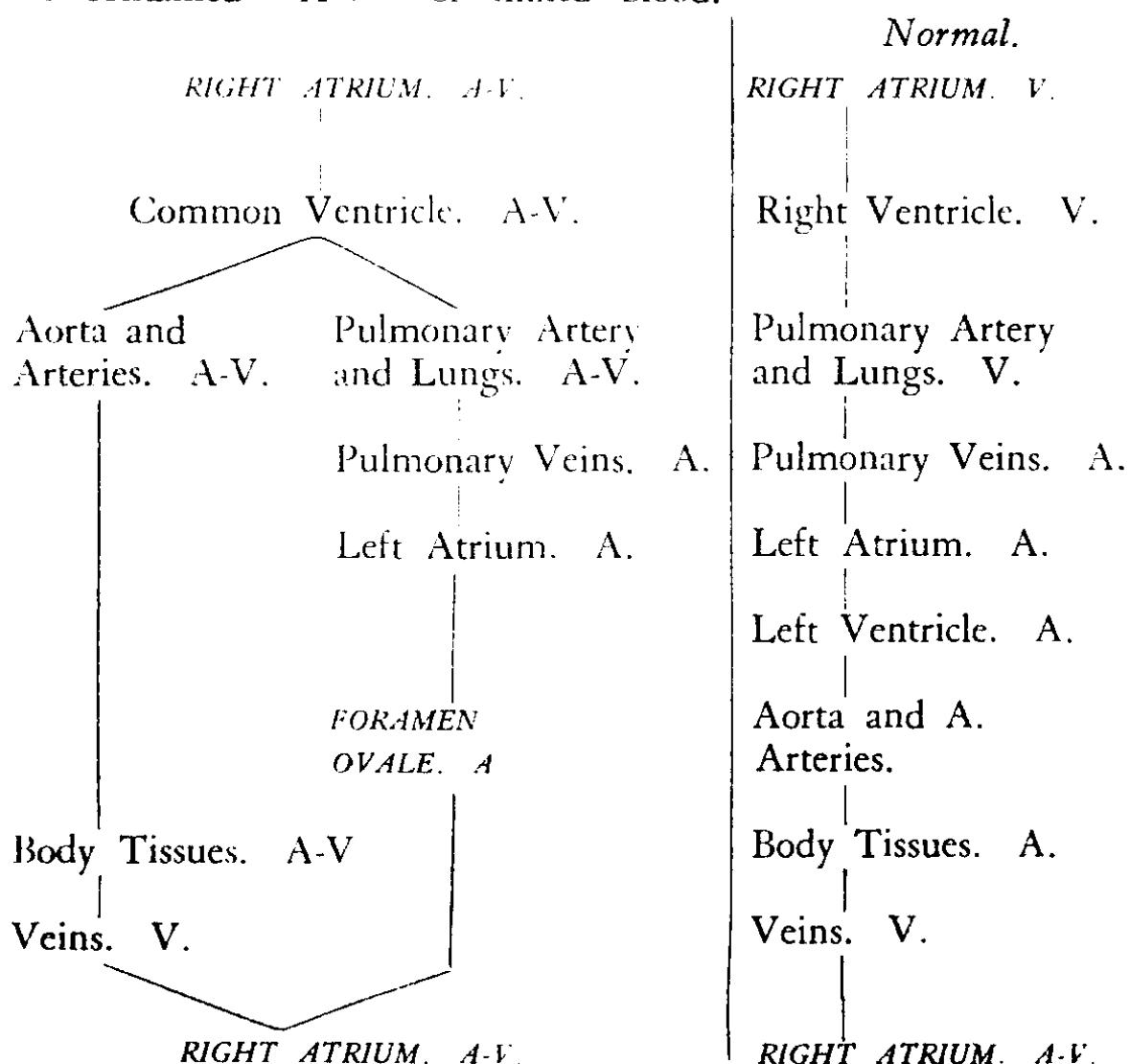
IV. THE MECHANISM OF THE HEART.

All the arterial blood from the pulmonary veins is received by the left atrium but there is no outlet to any other heart chamber except to the right atrium by way of the foramen ovale.

The right atrium must contain blood of mixed quality because it receives venous blood from the superior vena cava, the inferior vena cava and the oblique vein at the same time as it receives arterial blood from the left atrium through the foramen ovale. The blood in the ventricle, the aorta and the pulmonary artery must be of the same mixed quality.

In the scheme below is shown the course of the circulation of the blood in this case as compared with the normal. In this scheme "A," "V" and "A-V" indicate the quality of the blood in the different chambers and stages of the circulatory process, representing "arterial," "venous," and mixed blood respectively.

We may follow the blood from the right atrium which in the normal heart contains "V" or venous blood, but in this case must have contained "A-V" or mixed blood.



It is evident that the patent foramen ovale provides the sole means of oxygenation or of partial oxygenation of the blood in the systemic vessels and alone makes life compatible with the congenital defects in this heart.

The oblique vein which is such a conspicuous feature of this heart cannot have exerted any appreciable physiological effect on the

circulation. This vein does no more than to convey the blood of the left innominate vein direct to the right atrium instead of by way of the superior vena cava. The reader should compare the sketches C and D in Fig: III. The first is a plan of the normal arrangement of the veins of the thorax and the second a plan of the modifications in the presence of an oblique vein in a high state of development.

It seems that this vein is of embryological interest rather than of physiological importance.

It is difficult to assign any function at all to the ductus arteriosus in this case. This vessel connects the pulmonary artery to the aorta and both contain blood of the same quality. Again, the interest of this structure seems to be embryological rather than physiological, in this case.

The mechanism is inefficient for two reasons. This heart can supply the body tissues with only a partially oxygenated blood at best. On the other hand, the resources of the lungs are not made use of to the full, because the blood that reaches them is already of mixed character and not in need of complete oxygenation.

It is to be regretted that no clinical history is available. It would have been expected that an individual having an imperfectly oxygenated systemic blood would have exhibited cyanosis and other signs of circulatory embarrassment.

V. EMBRYOLOGICAL NOTES.

In this Section we offer the reader some reminders of certain broad facts in development that are relevant to our findings.

(i) *The Veins of the Thorax.*

In Fig: III will be found four sketch diagrams which are intended to present an outline of events in the development of the veins of the thorax and to furnish the history of the oblique vein of the left atrium.

Sketch A shows an early stage in which a pair of veins from the headward end join a second pair from the tailward end of the body. These veins are called the Anterior Cardinal (A.C.V.) and the Posterior Cardinal (P.C.V.) veins: they join larger veins which are directed medially and are known as the Common Cardinal Veins (C.C.V.) or the Ducts of Cuvier.

These Common Cardinal Veins join or form the lateral extremities of the bicornuate heart chamber known as the Sinus Venosus.

The Sinus Venosus directs its blood content to the single Atrium, whence by way of the Ventricle and the Bulbus Cordis it is transmitted

to the arteries. In this sketch the single median Inferior Vena Cava (I.V.C.) is shown entering the Sinus Venosus. In its origin this vein is quite independent of the Cardinal system, but it joins the Sinus Venosus together with other veins which are not relevant to our present purpose and are not represented.

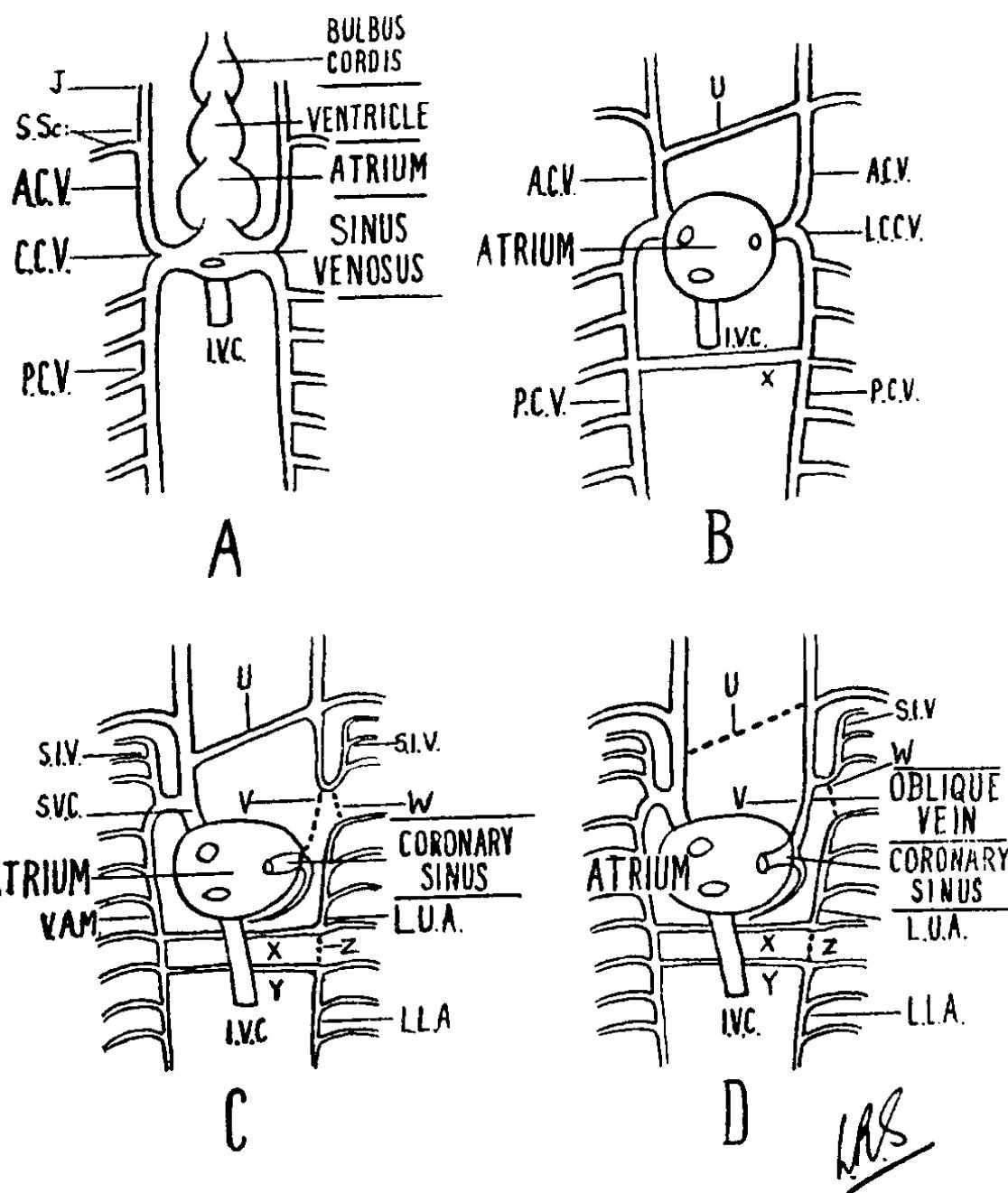


Fig. III.

These four sketch diagrams show stages in the development of the venous system. C is a plan of the final condition normally found. D shows the modifications which result in the formation of the oblique vein of the left atrium. Comparison of plan D with C will show that this vein is the representative on the left side of the superior vena cava.

Further explanations are found in the text.

The symmetrical arrangement of sketch A is soon to be lost. The left horn of the Sinus Venosus is retrogressive while the right horn enlarges and becomes incorporated into the Atrium; moreover

it is incorporated into that part of the Atrium which lies to the right of the developing inter-atrial septum.

In sketch B the tributaries of the Sinus Venosus have become separated from each other as a consequence of the blending of the two chambers. In sketches B, C and D the chamber named "Atrium" should be understood Right Atrium.

Further developments include a vein headward of the heart and connecting the two Anterior Cardinal Veins, indicated "U" in these drawings as well as a variable number of veins, "X" and "Y," tailward of the heart and connecting the two Posterior Cardinal Veins.

These cross communications influence the flow of venous blood to the right side of the heart and emphasise the asymmetry of the sinus venosus. It is not intended to discuss further the causes of this asymmetry.

The reader should compare the sketch B with C and D, of which C is practically a plan of the venous trunks of the adult thorax.

Sketch C shows that the Superior Vena Cava (S.V.C.) is the equivalent of the right common cardinal vein. The vein U together with that part of the anterior cardinal vein which lies headward of U becomes the Left Innominate Vein.

Both C and D show small paired veins extending headwards from the anterior cardinal veins. These veins lie on the dorsal wall of the thorax and are formed as the thorax expands headward with the vertical growth of the lungs. They are called the Superior Intercostal Vein (S.I.V.).

The right posterior cardinal vein becomes the Vena Azygos Major (V.A.M.) and joins the superior vena cava. This vein receives by cross communications the venous drainage of the very variable azygos system of the left side. Sketch C represents a fairly average arrangement of the veins of the left side. In the simplest of terms these may be called Superior Intercostal (S.I.V.), Left Upper Azygos (L.U.A.) and Left Lower Azygos (L.L.A.) Veins, from above downwards.

The stem of the left superior intercostal vein enters the left innominate vein (U) at or near its left extremity. The left anterior vein is represented by the proximal part of the left superior intercostal vein and by the inconstant vein "V" which joins it to the coronary sinus. This vein V then is the representative of the part of the anterior cardinal vein nearest to the sinus venosus or the left common cardinal vein.

Evidently that vein which is made up of the stem of the left superior intercostal vein and of V, is the equivalent of the superior vena cava on the right side. This vein V if it develops pari passu with its equivalent on the right side instead of receding becomes the

"Oblique Vein of the Left Atrium" or the "Oblique Vein of Marshall," and this is the condition shown in sketch D.

This is what we believe has taken place in the heart under discussion. Virtually two superior venae cavae are present. The left superior vena cava opens direct into the atrium of the heart in a position ordinarily occupied by the coronary sinus, to the right of the interatrial septum.

Unfortunately it was not noted if the left innominate vein (U) was actually present or not, neither were the connections of the left azygos system deserved.

The connections between the left superior intercostal vein and the lower members of the left azygos system are very variable, but two such connections are marked "W" and "Z."

It is of some interest to note that other animal types, e.g. the birds, the rabbit and the sheep normally have two superior venae cavae but in man the condition is rare.

(2). *Subdivision of the Atrio-Ventricular Canal.*

Proliferation of the sub-endocardial tissues takes place at four opposite places in the atrio-ventricular canal, viz: right and left, anterior and posterior. These proliferations, called "endocardiac cushions" grow into the canal where the anterior and posterior meet, fuse and divide it into right and left channels.

Subsequent growth of more permanent tissues into the endocardiac cushions forms the walls of the tricuspid and mitral orifices.

These events are shown in highly diagrammatic manner by four sketches at the top of Fig: IV, i.e. by A i, ii and iii.

The valves are formed from the material surplus to the formation of the first septum of the atrio-ventricular canal.

In this case we suppose that excessive and unregulated growth of the endocardiac cushions on the left side completely closed the mitral orifice, (sketch A, iv in Fig: IV).

(3). *Formation of the Aorta and the Pulmonary Artery.*

The roots of the aorta and of the pulmonary artery are derived from the primitive heart chamber called the "bulbus cordis." The proximal part of this chamber is destined to become incorporated into the ventricle in much the same way as the sinus venosus into the atrium. The subdivision of the bulbus cordis is brought about by the growth of endocardiac cushions in much the same way as the atrio-ventricular canal is divided, but with an important difference.

The endocardiac cushions of the *bulbus cordis* are elongated and they traverse the interior of the *bulbus* in a spiral manner so that the two divisions will lie, proximally right and left and, distally posterior and anterior. The cushions are named "right" and "left" *bulbar septa* from their disposition in the middle of the *bulbus*.

Proximally when the *bulbus* becomes included into the ventricle the *bulbar septum* joins the *interventricular septum* and the system of the *atrio-ventricular canal*.

The right division is adapted to the right *atrio-ventricular orifice* and becomes the *pulmonary artery*. The left division adapted to the left *atrio-ventricular opening* becomes the *aorta*.

These events are shown in highly diagrammatic fashion in sketch B, Figure IV.

Distally the *bulbus cordis* is completely divided into the *aorta* and the *pulmonary artery*. The *pulmonary artery* lies successively anterior, left and posterior to the *aorta* in consequence of the spiral arrangement of the *bulbar septum*.

In this specimen there must have been some failure in the development of the *bulbar septum*. Sketch C, Fig: IV shows what we suppose to have happened. The *aorta* and the *pulmonary artery* both overlie the *tricuspid opening*, with the axis of the *aorta* to the right of the axis of the *pulmonary artery*. It has been noted how these two vessels lie side by side at their exit from the ventricle.

The spiral arrangement of the *bulbar septum* has failed and there has been maladaptation to the *atrio-ventricular opening*. To what extent malformation of the *mitral orifice* is causative in the error in the *bulbar septum* or vice versa we can make no conjecture.

(4). *The Interventricular Septum.*

A semilunar ridge of muscle grows into the cavity of the ventricle making an indication of an equal subdivision. In order to completely divide the ventricle this muscle ridge, the *primary septum* of the ventricle, grows upwards and unites with the two other septa which also divide the heart, namely the *septum* of the *atrio-ventricular canal* and that of the *bulbus cordis*.

Sketch D, Fig: IV shows these septa in plan as seen in a hypothetical section of the heart viewed from the right side. The *primary muscle septum* is marked with vertical lines, the *septum* of the *bulbus cordis* with horizontal lines and the *septum* of the *atrio-ventricular canal*, derived from two *endocardiac cushions*, is shown in two stippled masses.

Normally these three elements of the *interventricular septum* grow together and fuse. The place of union remains non-muscular and is

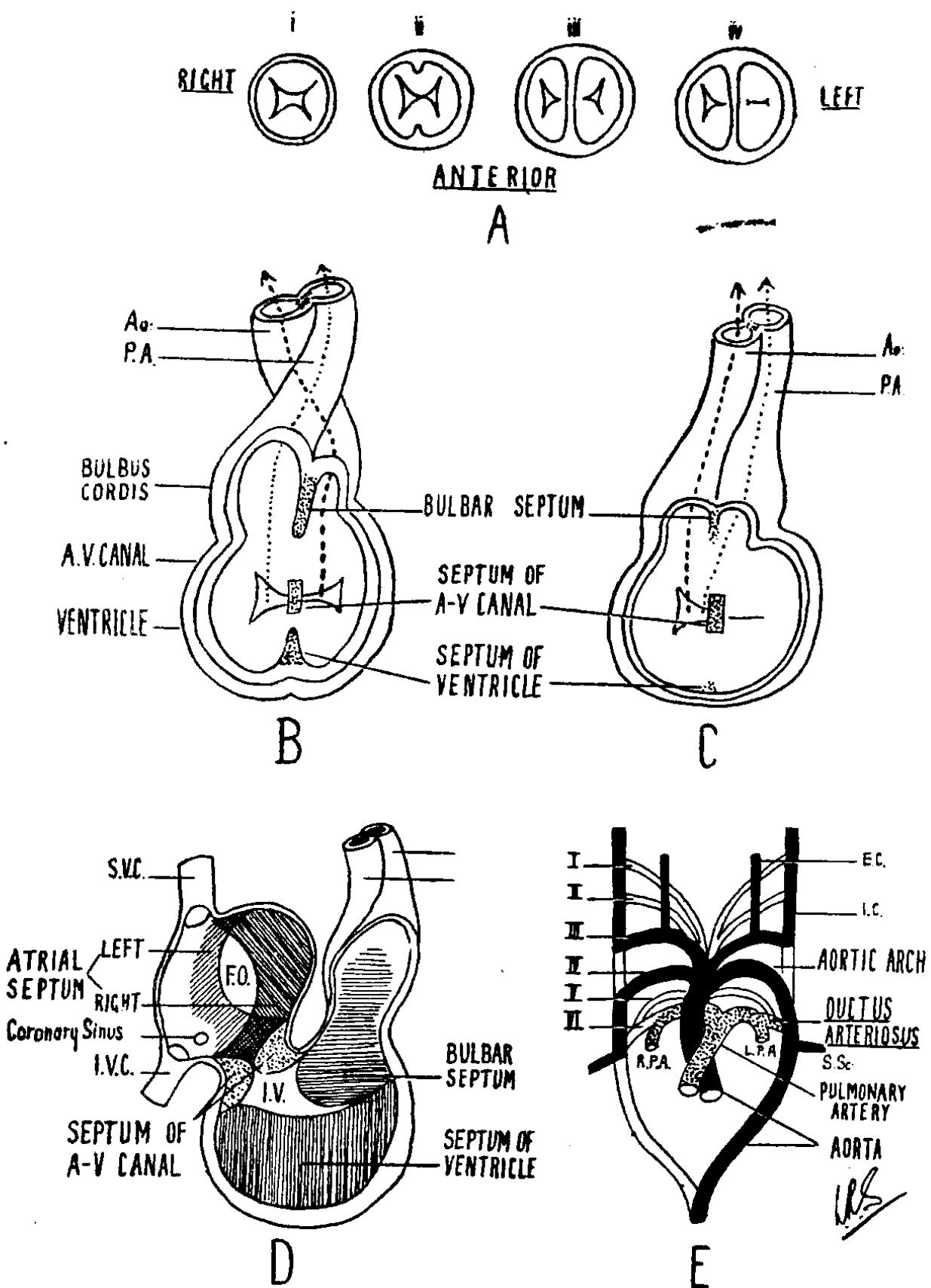


Fig: IV.

The sketches in this figure are explained fully in the text.

A represents very diagrammatically the mode of subdivision of the atrio-ventricular canal by endocardiac cushions as viewed from above. A IV shows the occlusion of the mitral orifice.

B shows the normal subdivision of the bulbus cordis by the bulbar septum and C the results of deficient and abnormal growth of this septum.

D is a plan of the whole septum of the heart and its various constituents. A hypothetical heart septum is viewed from the right side.

E is a plan of the primitive aortic arches. The vessels represented in double line normally disappear. These vessels in solid black persist in the systemic vessels and those stippled in the pulmonary vessels.

the thin translucent place in the septum of the heart called the "pars membranacea septi," (I-V in sketch D).

In this case the primary muscular septum has failed almost completely.

(5). *The Interatrial Septum.*

Two flaps of semilunar form grow from the interior wall and the posterior wall of the atrium as well as from the septum of the atrioventricular canal. The hollow edges grow the one forwards and the other backwards till the left flap has slid beyond the right and the interatrial gap is closed; then normally the two flaps fuse by their opposed surfaces.

If the two flaps fail to overlap and close the communicating gap, a foramen ovale with a vertical long axis (F. O. in sketch D) is left in the interatrial septum. It is to be noted that these events, indicated in the sketch plan D, take place to the right of the entry of the coronary sinus into the atrium i.e. left horn of the sinus venosus.

In this case there has been failure of the two valve flaps.

The compensatory nature of the foramen ovale in the presence of an occluded mitral valve has been noted.

(6). *The Ductus Arteriosus.*

Sketch E shows a familiar plan which indicates the fate of the various peripharyngeal arterial arches of which the great vessels of the thorax are the remainder.

In all six arterial arches are described; these are indicated on the left in the Roman numerals by which they are known to the embryologist. Those trunks that disappear are indicated by double lines, those that persist by solid black, or stippled in the case of the pulmonary trunk and its two main branches.

The ductus arteriosus is a relic of the sixth aortic arch which gives off the pulmonary arteries. Normally the connection between the left pulmonary artery and the aorta is reduced to a fibrous cord, the ligamentum arteriosum, soon after birth.

In this case it is difficult to interpret the persistence of this vessel as a necessary and compensatory arrangement as is sometimes the case. We have seen that both aorta and pulmonary artery carry the same blood of mixed quality and the three vessels are all of much the same size.

If the reader will refer to the description of a heart in "The Caduceus," Vol: 18, p. 66 et seq: he will see how a ductus arteriosus may serve a necessary compensatory purpose in the presence of defective development of the left ventricle. A similar purpose might be

served if either the aorta or the pulmonary trunk were narrowed, but in this case nothing of the sort can be discerned.

Probably the ductus arteriosus is the result of failure of the normal recession of an embryonic vessel and so comparable, in a measure, to the retention of the left superior vena cava or, if the term be preferred, of the left anterior cardinal vein, which has given rise to the oblique vein of the left atrium.

VI. SUMMARY.

In the preceding pages is described the heart of a child which exhibits the following major abnormalities of development.

- (1) The presence of the so called "oblique vein" of the left atrium or of Marshall in a high degree of development.
- (2) Occlusion of the mitral orifice.
- (3) Patent foramen ovale.
- (4) Almost complete absence of the interventricular septum.
- (5) Faulty formation of the aortic and pulmonary trunks.
- (6) Patent ductus arteriosus.

The mechanism of the circulation in the presence of these abnormalities is discussed in brief.

Notes on embryonic development refer to the following :

- (a) The oblique vein of Marshall.
- (b) The division of the atrio-ventricular canal.
- (c) The formation of the aorta and the pulmonary artery.
- (d) The interventricular septum.
- (e) The interatrial septum.
- (f) The ductus arteriosus.

Application of the facts of embryology furnishes tentative explanation of the various abnormalities noted in this heart.

VIII. ACKNOWLEDGEMENTS.

We acknowledge with thanks the kindness of Dr. Alvares who noted at autopsy a heart of unusual interest and allowed us to make detailed examination.

Acknowledgements are due to the publishers of Cunningham's Text-book of Anatomy VII edition, from which Fig: IV. D and E have been borrowed with some adaptation.

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SOME ASPECTS OF WAR SURGERY.

by

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INTRODUCTION.

Since this war began remarkably little has been written on the British side about surgical problems, and so, much of the material in this paper is based on experiences in past campaigns. We may have to wait some time yet before we get any very full accounts of surgical experiences. The problems of war surgery are created by the following factors :—

1. The extensive injuries produced.
2. The conditions under which they are produced.

These conditions in turn are :—

- (a) The extreme probability of wound infection.
- (b) The influence of cold, fatigue, hunger and thirst.
- (c) The long journeys over poor roads before wounded can reach hospital.
- (d) The number of casualties. In this connection it is of interest to recall that at the Battle of Messines in June 1917, eleven Casualty Clearing Stations and one small Advanced Operating Centre passed 10,434 wounded through their hands on first day. In three days they had passed through 16,238 casualties, and had operated on a total of 2,400.

The late Harvey Cushing recorded that at the third Battle of Ypres he was operating from 8.30 a.m. one day till 2 a.m. on the following day, and that during this time 2,000 casualties passed through his C.C.S. This experience was by no means unique.

It will therefore be well understood that a line of treatment considered to be best for a particular casualty from the purely surgical aspect, may have to be modified in war, where transportation and other considerations will interfere with the full realisation of the method.

TYPES OF INJURY.

Injuries in war result from wounds by bullets (Rifle and Machine Gun), by shell or bomb fragments and by explosion or the effects thereof.

A bullet, unless it is a ricochet, enters as a clean perforation, is readily turned aside by tissue of altered density such as a nerve and

at ranges under 500-700 yards causes an explosive type of wound at the point of exit. Bullets apparently wipe themselves clean as they penetrate the skin and infection is rarely deeply implanted.

Shell and bomb fragments are haphazard in their action, and usually carry in clothing and dirt with them. These wounds are almost invariably infected. In the Russo-Japanese War shell wounds formed 10% of the total; in France from 1912-1918 they formed 75% of the total. With the increase in efficiency of high explosive nowadays the casings of small bombs split up into very small splinters which are hurled almost horizontally at tremendous speed. They cause minute entrance wounds but have a devastating effect on bone and soft tissues. Even tiny wounds therefore must be fully explored.

An explosion occurring close to an individual may cause complete disintegration, or occasionally it may cause death with very few external signs of injury. In these latter cases the effects appear to be mainly on the lungs, where pneumothorax or rupture of parenchyma with haemorrhage, or a combination of these is produced. Petechial haemorrhages in the brain have also been observed.

Shell shock will not be considered as a result of explosions but burns of the skin from the flash are common and will be dealt with later.

TREATMENT IN FORWARD AREAS.

Humanitarian and military considerations alike demand that a wounded man shall be evacuated fast and far from the area of operations. Rapidity of evacuation depends on military factors and maybe enemy action, and evacuation may have to be delayed till nightfall. It has never been possible to reach agreement with an enemy to permit the establishment of areas close behind the lines where hospitals could be sited and be immune from attack. Demilitarisation of these hospital areas could be vouched for by neutral observers, and the resulting shortening of a wounded man's journey would do much to lessen our difficulties.

Medical action in forward areas resolves itself into two parts, the collection of casualties and their treatment. It calls for the thorough training of stretcher-bearers in their duties, so that wounded are rapidly collected and gently handled. Stretcher-bearers should be able to arrest dangerous haemorrhage, immobilise fractures and apply dressings; they should be drilled in the importance of maintaining body heat and getting wounded back quickly to where medical aid is available.

At Regimental Aid Posts and other points in the forward area where medical officers are available, there are certain indications for treatment:—

(i) Haemorrhage must be arrested. Practically all cases are controllable by firm bandaging, and packing should be reserved for deep inaccessible vessels. Any visible bleeding vessel should be picked up in artery forceps and ligated. A tourniquet is an exceedingly dangerous and very painful instrument, and its use can rarely be justified. The most stringent precautions are essential to avoid disastrous consequences when a tourniquet has been used.

(ii) Patients must be kept warm, and should be lying on blankets, as well as covered by them. Exposure by undressing and cutting off clothes should be reduced to a minimum. Hot water bottles or heated bricks should be applied to axillae and groins, and a guarded Primus stove will heat the space below the stretcher.

(iii) The wound should be dressed once and then left untouched.

(iv) Fractures should be immobilised as thoroughly as possible.

(v) Morphine in doses of 1/3-1/2 grain should be given for the relief of pain. It should not be forgotten that a number of officers and men carry morphine in war and use it when wounded.

(vi) Wounded men are invariably thirsty, and there is nothing better than hot sweet tea as a drink. There is no indication for alcohol at this stage.

(vii) The utmost conservatism is to be practiced as regards amputations, and only limbs hanging by a shred of tissue, with the neuro-vascular connections severed should be sacrificed.

(viii) An open pneumothorax demands urgent surgical treatment. If both pleural cavities are opened to any extent, death results, but where one cavity is opened the very slightest excitement or effort causes the phenomena of pendulum breathing, with a resulting increase of carbon dioxide in the blood, and mediastinal flutter with impairment of the venous return to the heart. Such wounds must be closed immediately either by deep skin stitches, or if there is a large defect in the thoracic cage this should be packed with gauze and covered by a layer of air-tight material such as jaconet before bandaging.

WAR WOUNDS.

It is unnecessary to deal in detail with the organisation of medical units, but in any unit to which falls the duty of receiving and sorting wounded in large numbers, it is vital to have to have an arrangement for extricating the moribund, selecting cases for the Resuscitation Ward and the Pre-Operation Ward, and for side-tracking special cases and those lightly wounded.

The ideal is to submit all wounds to early operation. In war the ideal is rarely attainable, and the percentage of wounded operated

on in France during the Great War varied widely between 10% and 65%, the latter figure being attained during slack periods.

In war all wounds are to be regarded as infected, and operation should be performed for the removal of foreign bodies, etc. Thereafter, rest for the patient with elevation and immobilisation of the part are essential, though the factors mentioned earlier may prevent the realisation of this ideal.

In through and through bullet wounds, infection appears to be wiped off as the missile enters and the track is rarely deeply infected. The skin heals first and the track later, and a little care is sometimes necessary to avoid contractures, the result of muscle injury. A retained missile may not always demand or be susceptible of immediate removal, and any attempt at removal at a later date should always be preceded by passive immunisation against tetanus, and the operation wound should always be drained since staphylococci as well as spores can retain their viability for long periods when encapsulated in the body.

The great majority of wounds result from shell and bomb fragments, and these missiles carry in infection from skin and clothes. For the first 12 hours (this period of course is variable), organisms lie on the surface of the wound and begin to multiply but do not invade. They can be removed by mechanical cleansing, or at any rate any not so removed can be dealt with by the tissues without the appearance of frank suppuration. This constitutes the stage of wound contamination.

After 12 hours, the organisms continue to multiply and invasion occurs, with passage of infecting microbes beyond the reach of surgical removal. This constitutes the stage of wound infection.

The treatment of contaminated wounds calls for the surgical removal of all foreign bodies, all dead and damaged tissue especially muscle (healthy muscle bleeds when cut and contracts when pinched). Haematomata should be evacuated, and it may be noted that they tend to follow tissue planes along the course of nerves and vessels. Skin removal should be as conservative as possible, and due regard must be paid during the operation to intact nerves, vessels and tendons, the sheaths of which alone may be delicately cleansed. If bleeding from a vessel will not stop as a result of force-pressure, the vessel may be ligated, but only the mouth of the vessel should be included in the ligature. It is bad surgery to take up for ligature a mass of tissue, in the midst of which is a bleeding vessel, for the included tissue will only necrose and produce a suitable medium for the culture of organisms. Divided nerves are brought together by fine silk through the perineurium, and severed tendons as a rule are left to be united at a subsequent operation, after healing has occurred. Haemostasis must be as complete

as possible, and no attempt to approximate tissue planes by catgut or other sutures is permissible. At this stage the surgeon must select one of several available methods for the further treatment of cases in this class.

(A). In the few cases in which he is well satisfied that he has secured a wound capable of primary union, in which skin can be approximated without tension (relieving incisions being permissible to achieve this end), and if his patient has not got to be evacuated, and can be retained at rest and under observation for at least a week, then the surgeon may undertake primary suture. In these cases drainage is better omitted, but as its purpose is to allow escape of fluid, and so to diminish tension when haemostasis is incomplete, drains may sometimes be employed. They vary in form from a few strands of silkworm gut brought out between two stitches, to a rubber tube introduced through a stab incision placed separately to the main wound and in a dependent situation.

The next step is to secure immobilisation, and plaster of Paris is usually preferred to other forms of splinting for this purpose. If plaster is used, a window must be cut to expose the wound and elevation of the limb is essential to prevent oedema, and consequent delay in healing.

(B). At the end of his revision operation the surgeon may not be convinced that he has secured a wound which he can safely close by suture, or, alternatively the patient may have to be evacuated without an intervening period of rest.

- (a) In the first case where the patient can be retained but primary closure seems risky, the wound may be filled with gauze soaked in 1-1000 watery solution of acriflavine, or with vaseline gauze or with petroleum jelly, the limb immobilised in a plaster cast and elevated. It may sometimes be possible to close such wounds by suture within 72 hours (delayed primary suture), or preferably they may be left to heal under a closed plaster.
- (b) If the patient has to be evacuated, skin suturing is not undertaken. Such patients always arrived at Base Hospitals in France with the stitch holes inflamed, and the sutures required immediate removal. In such cases the wound may be filled with medicated gauze or jelly, the limb immobilised and elevated and the patient sent on to the Base. Any form of rigid plaster of Paris cast surrounding a recently operated limb of a patient sent for evacuation, is a menace to that limb, and such a method of immobilisation must be used only when movement during transportation is at a minimum, as during aerial journeys, or where the most careful individual

watch can be kept over patients during the journey, and steps can be taken to remove the cast if necessary. Such conditions will rarely be satisfied in war. Plaster casts used under these conditions should always be split to allow easy removal.

(C). When the stage of frank wound infection has set in, the practice in the British Army at the end of the Great War was to treat these wounds on the modified Carrel-Dakin system. Dakin's fluid had as its active principle hypochlorite of soda, and in the British modification Eusol, the active principle hypochlorous acid was substituted. The aim was to effect sterilisation of wounds by chemical means, but an essential part of the method was a thorough but gentle débridement, with removal of foreign bodies and dead tissues. Incisions deliberately avoided dependent parts, and if any openings were placed dependently, these were plugged. The chemical solution was led to all parts of the wound by a system of small bore rubber tubes, and instillation was either continuous, which created many nursing problems, or was carried out every 2 hours.

The hypochlorous acid in Eusol remained active in a wound for about $1\frac{1}{2}$ hours. The degree of wound infection was charted as a result of a regular examination of smears taken from the wound, and when the number of organisms fell to nil or only 1 per 10 or so fields examined, secondary wound suture was undertaken.

At the present time the principles governing the treatment of infected wounds may be stated as follows:—

- (i) Revision of the wound with thorough removal of foreign bodies and dead tissues.
- (ii) Provision of dependent drainage.
- (iii) Immobilisation and elevation of the limb.
- (iv) Non-interference so long as the patient is not in pain, and shows no rise or only a slight rise of temperature.

After surgery the important things are immobilisation and elevation. Immobilisation may be very difficult to attain if patients have to be evacuated from front to rear, and this is the weak point in this line of treatment. It is however a drawback common to all methods in war.

One other type of wound must be referred to before leaving the subject, and that is the type showing a flaring, spreading, non-gaseous infection, the type at the height of the invasive period and before resistance has developed. This calls for specially gentle surgery, with sparing incisions to avoid opening up new tissues to the infection. It is essential to immobilise the limb completely and to elevate it.

Sulphonamide compounds must be considered in giving any account of war injuries. As regards the treatment of infected wounds,

it is not necessary to go into details since this corresponds closely with the practice in civil life.

In October 1939 a War Office scheme was put forward for the prophylactic administration of Sulphanilamide to wounded men. It was carefully pointed out that no-one had any exact knowledge as to the manner in which shocked men would respond to the drug and so caution was advised. The scheme was modified in November 1939 and was re-cast in March 1940 at a meeting of the Medical Society of the British Expeditionary Force in France, and involved the administration of 13.5 grammes of Sulphanilamide over a period of 4 days; 1.5 grammes at once dissolved in lemon juice to aid absorption; 2 hours later the patient had 0.5 gramme only partly crushed to delay absorption, and then 0.5 gramme 4-hourly for 4 days. This dosage was based on chemical examinations of the blood in healthy men who had taken known quantities of the drug, and so still, care was advised when dealing with shocked patients. The results have been encouraging, but it is hardly necessary to say that Sulphanilamide given prophylactically can be only an adjuvant, though doubtless a powerful one to skilful surgery. It is left to the discretion of the medical officer in charge of the case to decide when this method is to be utilised, and Sulphanilamide, Sulphapyridine and Sulphathiazole all have their advocates.

Opinions seem to vary as to the value of Sulphanilamide applied locally to wounds, and I will content myself with the observation that nothing that is known of the mode of action or supposed mode of action of Sulphanilamide in any way contra-indicates its use locally.

A considerable number of wounded are not fit for operation without preliminary treatment, and this delay is imposed usually by the presence of a state of shock.

SHOCK.

I mention the condition known as local shock only to dismiss it at once. It is characterised by immediate numbness and muscular paralysis of a limb following upon injury by gun shot. It is not the result of a nerve lesion because of its distribution, and it accounts for the absence of shortening in recent compound fractures. It has served to render painless the amputation of a shattered limb. It lasts for a few hours and is apparently due to the vibratory effects of the missile on main nerves.

Regarding that complex state we know as shock, many ingenious definitions have been given, but James Latta of Edinburgh in 1795 avoided all speculation when he declared "Shock to be due to a collapse of the circulation following on severe injury." I will not inflict upon you any theories as to the causation of shock; the clinical state is well

known, and our problem in war concerns men suffering from the effects of haemorrhage, whilst a nerve barrage originating in the traumatised area bombards the nervous system bringing about a lowering of blood pressure through a mechanism which may act in several ways. In addition there is often toxæmia from sepsis to be faced, whilst fear, anger, cold, fatigue and pain all combine to retard recovery.

In treatment therefore there are certain clear indications:—

- (i) To arrest fluid loss.
- (ii) To place a barrier in the path of the nociceptive impulses.
- (iii) To replace fluid loss.
- (iv) To promote warmth.
- (v) To remove sources of infection.
- (vi) To promote sleep.

Certain of these indications call for the performance of some kind of operation, and the question of when operation is to be undertaken is one which demands the exercise of skilled and trained judgment. A working rule for dealing with large numbers of casualties laid it down that operation was not advisable when the systolic pressure had fallen below 90. Restorative measures were to be carried out first, but obviously the beneficial effects of such measures will be nullified in the presence of sepsis. Operations should be rapidly but thoroughly carried out; handling should be gentle and chilling avoided; "cooking" of a patient on the other hand should be guarded against.

In the forward area, pain must be combatted by morphine, and there can be nothing but condemnation for the suggestion that spinal anaesthesia should be used to block the nerve barrage in lower limb injuries in advanced positions. In hospitals further back spinal anaesthesia may have a place, but it would be harmful to use it in any case where haemorrhage had been or was considerable, since it will merely aggravate the condition by stagnating blood in the anaesthetised area. However, by replacing lost blood, and by mobilising it through the agency of hypertonic intravenous infusions, spinal anaesthesia might have a useful part to play, though Gordon Taylor says that no-one but a lunatic would employ it in the war surgery of the abdomen.

Gas and oxygen occupied a commanding position as an anaesthetic by 1918 though a skilled anaesthetist was necessary to produce a deep anaesthesia. Ether given by the open method was the most useful general purpose anaesthetic, but we must wait longer to discover how the anaesthetists will solve their problems this time.

TRANSFUSION.

Fluid replacement may be effected by the mouth but a patient suffering from shock may be vomiting, and in any case the proper substitute for blood lost by haemorrhage is blood.

Transfusions of citrated blood have had their greatest successes in cases where much blood has been lost, and when this war began experience in Spain and elsewhere led to the setting up of blood banks where blood could be stored and transported thence rapidly to the required spot. It became evident later that blood so stored began to deteriorate almost immediately and that after 72 hours the formation of a gelatinous clot interposed certain technical difficulties in the way of the actual giving of the blood, and very careful filtering was necessary. Changes occurred in the blood itself, and though no ill-effects have followed the use of blood stored as long as 34 days, it appeared that in practice storage for longer than 5-14 days or so was not desirable.

It was considered by many that it was only haemorrhage which called for the cells in blood, and in pure wound shock, in post-operative shock and in burns, serum or plasma separated off were shewn to have a value at least as great as citrated blood when transfused. This is a most important observation for both serum and plasma can be dried off and stored indefinitely, and a way appears to be open to minimise the considerable waste of blood which occurs where this substance is banked in any quantity.

I do not propose to go into details of collection and storage, but we may note in passing that it does not seem necessary to group the recipient before giving plasma transfusions, that 1 pint of citrated blood will give about 250 c.c. of plasma and that this can be evaporated off to leave about 20 grammes of a powder which will keep for years, is readily soluble in distilled water and this fluid can be filtered bacteriologically thus ensuring its sterility.

In an admittedly small number of cases it has recently been reported that after certain operations where blood loss had been considerable, an increase occurred in the patient's red cells after plasma transfusion with a notable improvement in the patient's condition. It was suggested that the effect of the plasma was to return to the circulation some or all of the stationary side-tracked corpuscles. This awaits further observations, but if confirmed would suggest that plasma might also be used for the treatment of haemorrhage.

All these matters are of the greatest importance in war surgery. We are far from finality, and we would do well to remember that the chemists may produce for us an artificial solution which will be an effective substitute for plasma, and thus effect a further great saving of most valuable material.

TETANUS.

The present day mortality of tetanus is 40%-70%, which is only a little better than before antitoxin therapy was introduced, and in peace the injuries which produce tetanus are punctured wounds, wounds made by splinters entering the skin, abrasions and lacerations, and compound fractures. The treatment of piles by injection has resulted in tetanus. These trivial injuries probably do not receive prophylactic antitoxin because of their apparently slight importance.

As regards prophylaxis, in the Regular Army to-day men are given an opportunity of obtaining active immunisation by two doses each of 1 c.c. tetanus-toxoid at a 6-week interval. The action of the toxoid has been considered by some authorities to be enhanced by the simultaneous administration of the typhoid-paratyphoid (T.A.B.) vaccine, but the practice in the Army is not to combine the two, since the unpleasant reaction sometimes produced by the vaccine might be attributed by the troops to the effects of the toxoid.

Experimentally, considerable but slowly decreasing immunity has been proved to be conferred by tetanus-toxoid, but much time will elapse before enough evidence is accumulated to justify us in dispensing with the passive immunity so brilliantly conferred by prophylactic antitoxin. For the present therefore, in a wound which impresses as a potential harbourer of spores or bacilli, a single dose of 3,000 units (international) of antitoxin is recommended. When dealing with infected wounds, where a considerable quantity of toxin might be produced, it is wise to repeat the prophylactic dose on the second day, again on the seventh day and sometimes later also. The small volume in which this dose is now contained, has not unfortunately affected the incidence of serum sickness, and in addition to the usual skin manifestations, it is well to be alive to the possibility of spinal or cranial nerve lesions occurring, while even a general paralysis has been reported.

Therapeutically, the value of antitoxin is in dispute; it is held by some that once the toxin is fixed by the nerve cell it cannot be displaced and consequently antitoxin will be of value only in neutralising circulating and tissue toxins. Even if antitoxin is given therapeutically, the route also is a subject of varying opinions. Cole gives 200,000 units intravenously immediately after diagnosis; he gives an additional 50,000 units intramuscularly once a week if the wound has been specially deep or infected. Otherwise he considers the initial dose enough. Othrs give 20,000-80,000 units a day spread over the various routes, and the total amount given ranges from 200,000-900,000 units. There is no object in choosing the intra-thechal route. This only causes additional disturbance in a patient where any disturbance is harmful. No wound treatment is undertaken till antitoxin is freely circulating, so that at least an hour should elapse after intravenous

administration. Even healed wounds are excised, and the following case serves as an illustration of how tetanus spores may survive.

In 1928 Bonney performed a myomectomy, and the patient, following the operation developed generalised tetanus. In 1938 the same patient was submitted to sub-total hysterectomy, and at this operation the old abdominal scar was excised and cultured. *Cl. tetani* were grown whose toxigenicity showed no diminution when compared with that of representative strains, and that was after presumably 10 years in spore form. In this case the surgeons were fully alive to the possibility and had saturated the patient with antitoxin before operation. Tetanus did not develop.

It is always necessary to give antitoxin before operating, even at a late date on any war wound which might harbour spores. A patient suffering from tetanus dies from exhaustion, and glottic spasm but not from any neurological action of the toxin. Bromides before reflex spasms begin, and avertin in full doses after the onset of spasms are indicated to promote rest and avoid respiratory embarrassment, while oxygen intranasally is most useful. All nursing and other attentions should be carried out whilst the patient is deeply under the influence of the avertin.

Certain abnormal forms of tetanus are described and appear to occur in patients who have been only partially immunised by antitoxin.

- (i) Local Tetanus:—Round a wound which is a little septic a patient who is showing slight pyrexia begins to experience muscle cramps. These may be of a tonic or clonic nature, and they are excited by outside stimuli such as a noise or an attempt to dress the wound. The patient has an anxious expression, and there is a little trismus and some stiffness of the neck. The cramps may spread to the other limb, but there is no risus. Trismus disappears rapidly under treatment but local spasm is more obstinate. It appears to be possible for a local to merge into a general tetanus as protection afforded by the antitoxin fades.
- (ii) Cephalic Tetanus:—The form is always associated with head wounds, and several types are described:—
 - (a) Trismus with contraction of facial muscles are the features.
 - (b) Partial or complete facial paralysis sometimes occurs.
 - (c) There is also an ophthalmoplegic form, where the wound is of the eye or is close thereto, which is associated with ocular paralyses.

Other still rarer forms have been described, and while it is always necessary to be alive to the possibility of modified tetanus occurring, hysterical manifestations must be excluded before arriving at a diagnosis.

GAS GANGRENE.

Acute traumatic spreading emphysematous gangrene is essentially a disease of muscles, and is rarely dangerous unless muscle is involved. The organisms responsible are the saccharolitic group *Cl. welchii*, *septique* and *oedematiens*, while *Cl. sporogenes* which usually accompanies *Cl. welchii* is proteolytic. These organisms are introduced by the projectile, but to produce dangerous effects there must be interference with the blood supply of muscle. Some muscles derive their blood supply from a single vessel, while others have several sources of supply, but in the body of a muscle, whilst the capillaries anastomose to some extent, there is no connection between larger vessels. If there is a single source of supply to a muscle blockage of the supply will result in the death of the muscle, but where there are several sources of supply, blockage of one vessel will cause death of the muscle in its area of distribution.

These facts explain certain clinical experiences:—

- (i) A dead or gangrenous muscle may be found in the midst of healthy muscles.
- (ii) The disease may be arrested at one point in muscle.
- (iii) A muscle obviously healthy at the time of a débridement may subsequently be found dead, the result of inadvertent interference with its vascular supply by the operator.

Interference with the vascular supply of muscle in war may be caused by several factors:—

- (a) Lowered blood pressure due to shock.
- (b) Tight bandaging, or gas already produced in the tissues, pressing on main vessels.
- (c) Direct pressure on vessels by fractured bones or projectiles.
- (d) Pressure from dammed up discharges or from packing.

The incubation period may be exceedingly short, just over 3 hours has been reported, and in the case of a man in the resuscitation ward who shews no response to ordinary methods of treatment, other causes should be sought and amongst these is gas infection in the wound. Three types are described:—

- (i) A group type where infection is limited to one muscle or a group of muscles.

- (ii) A segmental or massive type, where gross infection of the muscles of a limb occurs distal to an arterial lesion.
- (iii) A fulminating type which differs only in degree from the others, but where no treatment seems to arrest the disease which spreads into the trunk and ends fatally.

Preventive measures in forward areas consist in the minimising of the effects of shock and cold with their fall of blood pressure, careful immobilisation of fractures, avoidance of tourniquets and care in the application of encircling bandages to allow for subsequent swelling of wounded limbs. Packing used to control oozing may press on vessels or dam discharges.

In the diagnosis of established infection, X-rays may sometimes forestall clinical examination and it has been claimed that the radiological diagnosis is complete many hours ahead of the clinical diagnosis. It may be that radiological methods of diagnosis will have their greatest success in cases which develop late or in cases in which the wounds have already been revised or where the severity of the infection has been lessened by serum or chemotherapy. As regards treatment, we have available surgical operation, serum therapy and chemotherapy. It should be remembered that the presence of anaerobic gas producing organisms in a wound does not necessarily mean that gas gangrene will develop. Such an occurrence however, would be the signal for the exercise of the utmost vigilance. Treatment by X-rays has also been mentioned, and it is possible that the method may have a future, but so far as I am aware experience is limited and the value of this form of therapy cannot yet be assessed.

No therapy can be of avail without preliminary surgical operation designed to remove foreign bodies, dead tissues and establish drainage. The scope of surgical operation by the end of the last war was somewhat as follows:—In a Group case with a patient in good shape the usual mechanical cleansing was carried out, affected muscle being removed through adequate longitudinal incisions until healthy, bleeding and contractile tissue was reached. A muscle might be removed from its origin to its insertion if need be, but surgical manipulations were required to be particularly gentle, and blood vessels carefully preserved. As gas spreads widely in the subcutaneous tissues, the extent of tympanites and crepitations was no guide to the level of the disease.

In a patient in poor condition with Group gangrene and a fracture of a long bone, amputation was carried out through the fracture. This was a provisional amputation only, and affected muscle above the level of the amputation was removed through adequate longitudinal incisions.

When doubt arose as to the level at which to amputate, and crepitations were present above the level of the injury, muscle tissue

was exposed by incision and the surgeon was guided by the level of the disease in muscles in arriving at a decision. In all amputations drainage was essential and it was advised that in all cases skin flaps should be cut but stitched back to leave a raw stump. For gas infections below the knee, amputation through the thigh was never necessary and in these cases the level chosen was through the knee joint or through the head of the tibia with removal of the heads of the gastrocnemius.

In the Segmental type with arterial damage, the only question was where to amputate, and the same consideration was utilised in arriving at a decision. Amputation was carried out at the lowest level of living muscle. Amputation at or near the hip-joint was almost invariably fatal, and a patient with a severe gas infection of a limb who was pulseless was one on whom it was a waste of time to operate.

There seems to be no doubt of the value of the Sulphonamide compounds in the treatment of gas gangrene. They obviously cannot revivify dead and stinking muscle nor can they remove foreign bodies and clothing, and so must be employed as a handmaiden of careful and gentle surgery. Surgical treatment might be preceded immediately by the giving of a Sulphonamide, and there is experimental evidence of the different therapeutic efficiency of different compounds in the presence of different infecting organisms. So far as I can ascertain at present Sulphapyridine is superior to Sulphanilamide in the gas gangrene of war, but we have also experimental evidence that Sulphapyridine used with anti-bacterial serum or better still in combination with anti-toxin gives the best results of all. This last observation awaits confirmation in man, but there does seem reason to hope that by using the Sulphonamides probably along with serum we may diminish the severity of the infection, and so certain cases may be spared amputation, the mortality may be lowered, severe cases turned into less severe, extensive operations made less necessary and so on, but I am convinced that we must not neglect early surgical treatment of these conditions.

Serum alone has its uses both as a prophylactic and as a therapeutic agent, but it seems at present to be used in combination with the Sulphonamides in both cases.

BURNS

In any scheme for casualties in modern war it is necessary to make provision for the treatment of burns, the result of explosions. In air raid casualties amongst the civil population, burns from the action of incendiary bombs may be common, but the burning effect of high explosive is not sufficiently recognised. Many modern defensive positions are constructed of steel and concrete, and in addition to being carbon monoxide traps unless carefully ventilated, offer

no escape from the flash if penetrated by a high explosive shell which does not kill outright. Burns are, of course, subject to the same delays as other war injuries in reaching hospital treatment.

It may be recalled that in 1937 H.M.S. Hunter struck a mine, and that the German battleship Deutschland was bombed, both in Spanish waters. The Hunter cases, 20 in number were landed in Gibraltar 48 hours after the accident, and the Deutschland cases, 55 in number were landed in the same fortress 24 hours after the bombing. The Surgical Specialist in Gibraltar, Major C. B. C. Anderson, Royal Army Medical Corps, afterwards wrote a very interesting account of these cases, none of whom was seen under 24 hours. Of the 75 cases there were only 19 in whom burns were not the main injury, and it may be that this experience will be repeated in war, particularly when troops are occupying fortified positions. In his account, Major Anderson called attention to certain features of these cases. In a large majority, foreign bodies were driven into the tissues, and by the time they reached Gibraltar they were all grossly septic. Surprise was expressed at the extreme degree of shock shewn. Various first aid applications had been utilised but there had been no attempt at débridement prior to admission to hospital, and where infusion would have been valuable, not one of the German cases had superficial veins available. He expressed the opinion that under service conditions, with established sepsis, and having regard to the number of casualties, the tannic acid method of treatment may not be the best for such burns. He further pointed out that many of these men are so ill that each can very well take for himself the whole-time services of a nurse for the first 48 hours, and also that special departments may have to be set aside for their reception. He suggests as a first aid measure the old simple dry dressing, thus presenting for effective débridement, burns untouched by chemicals or oils.

For treatment after débridement, he employed 10% eucalyptus in sterile vaseline changed only every 72 hours or thereabouts, and he lost only 5 cases, all German. Three of these had fractures of the skull as well and all had over 80% of skin surface burned. It may be that the virtue of the eucalyptus vaseline dressing which Major Anderson employed, may reside in its bland occlusion of the burned area.

Recent work on burns is well known, and it is unnecessary to deal further with the subject except to say that troops with burns from front line units may not reach hospitals from 8-12 hours or longer till secondary shock and acute toxæmia are well established. Débridement should still be the object, but the condition of the patient may interfere with early active measures. Fluid loss from the burned area requires replacement, and if the suggestion is accepted that the absorbed toxins act deleteriously on liver cells, glucose should

be added to the fluid infused. The virtues of an occlusive dressing left untouched should not be overlooked, and the Sulphanilamide group will prove most valuable against the haemolytic streptococci which in these explosive burns seem almost always to be present. The complications do not differ from those of ordinary burns, but otitis media usually results from infection through a drum ruptured at the time of the explosion, and ears therefore should be treated as carefully from the beginning as they are in fractures of the middle fossa.

MAXILLO-FACIAL INJURIES.

These injuries call for the highest form of skill in their treatment and special hospitals in England are provided in war for the purpose. It is within our province however to present these cases to the dental and surgical artists who staff the special hospitals, in the best possible state, and some of the principles involved are as follows:—

First aid treatment and treatment in forward areas is of a life-saving nature only, and thus calls for the prevention of suffocation and the arrest of haemorrhage. Suffocation results from loss of the control of the tongue, and "lying" cases therefore, must be transported in the prone position, with the head over the end of the stretcher. If the patient can walk he should do so with the head well forward. Stretcher-bearers must be taught the importance of keeping the tongue forward, but to maintain this position a suture may be necessary. For haemorrhage, correct posture will help, but external wounds should be plugged and haemorrhage controlled by digital pressure if need be. The Japanese perform tracheotomy and plug the mouth in such cases.

On arrival in hospital, shock requires attention and an adequate air-way must be ensured. Displaced hard and soft tissues are replaced in their correct positions at the earliest moment and retained there, provided that no undue tension is thereby imposed on replaced soft tissues. Where much bone is lost, raw-bone margins should be covered by mucous membrane if possible, and at any margins mucous membrane should be united to skin by catgut. So long as bone fragments retain even the slightest of periosteal attachments, they should not be removed. Over-approximation is to be avoided if there has been a large tissue loss, or if nose, mouth or eye cavities are involved. Surgical wiring of fragments in compound fractures is absolutely contra-indicated. Sub-mandibular drainage is essential from the outset, and the Dental Officer's co-operation is necessary, but his part of the operation, with its conservation of teeth, inter-dental wiring and other methods of fixation is outside the scope of this paper.

It was the general experience in the Great War that tracheotomy was rarely necessary, and that loss of teeth permitted vomiting after

the general anaesthetic usually employed. A feeding cup is necessary with a rubber tube to deliver nourishment and drink to the back of the throat, and the mouth is thoroughly washed with sodium bicarbonate solution after every meal and frequently otherwise. Frequent dressings are of course necessary.

AMPUTATIONS.

Some 30,000 patients suffered amputations of legs during the Great War, and thus, this subject is one of very great importance. In modern surgical practice the indications for amputation in any injuries of the arm and leg are becoming fewer, though in war we must be prepared for a higher rate to prevail because of the inevitable delays before hospital treatment can be obtained.

It is not proposed to give any list of indications for amputation but two conditions which make it imperative are a fracture of a long bone associated with a wound of the main artery of the limb, and a wound of the main artery when there is also massive gas infection of the limb. On the other hand, provided the neuro-vascular bundle is intact, limbs most dreadfully injured can be saved.

Guillotine amputations are indefensible; in the most urgent cases flaps of skin and subcutaneous tissue take only a moment to cut, and they can be stitched back to leave a wound similar to a guillotine amputation, and brought down later when infection has been overcome. Drainage of stumps in war surgery is essential.

The experience of amputations of those in charge of the Queen Mary Hospital for limbless soldiers at Rochampton is very large and probably unrivalled, and Dr. Kelham mentions the following points as highly important.

- (a) Stumps *must* be poorly covered. Flaps should contain only skin and subcutaneous tissue. Muscles are sectioned just distal to the point of bone section, and in the leg the fibula is cut 1 inch shorter than the tibia.
- (b) Nerves are crushed and cut 1 inch above the level of bone section, and the stumps of the nerves are injected with absolute alcohol. It is undesirable to pull nerves far down before cutting them.
- (c) Nerve bulbs are the usual finding after amputations, and they give rise to symptoms only if they are adherent or specially pressed upon. Alcohol is liable to cause nerve pains when drunk after amputations, and beer is worse in this respect than whiskey.
- (d) In the case of the femur, within 3 months a bony spur grows upwards and inwards from the point of section for about 1

inch. So long as the overlying tissues are not adherent, no treatment is called for, but if these are adherent, the scar should be excised but the spur left untouched.

- (e) Prostheses can not be fitted till the stump has fully shrunk. This process takes about 3 months, and before fitting it is essential that there should be no oedema, and that the stump should be able to stand fairly rough handling.
- (f) It is sometimes said that in the immediate post-operative period, the sandbag often employed is better placed on the stump, instead of below it to avoid contractures.

Referring to individual amputations some points of detail are:—

Arm.

The utmost conservatism must be practised and "set" operations are rare. For prosthetic purposes however, flaps should be of skin and subcutaneous tissue only; they should be equal, and the scar should be transverse and terminal. The levels recommended as best for artificial arms are 7"-8" below the tip of the acromion, and 6"-7" below the elbow. No artificial arm, even when used with the skill of long practice is in the remotest degree any substitute for a flesh and blood arm, and a recent comment to me by a patient who had years ago suffered an above-elbow amputation is illuminating. Speaking of an artificial arm which he had bought at considerable expense, he declared; "I could impress on-lookers by my mastery of my arm, but I could not impress myself, and I have long discarded it." When therefore, amputation of an arm has to be resorted to, regard should be paid to the prosthetic levels only when the injury brings the essential level of amputation to at or about the prosthetic level. Any portion of the hand is of the utmost value, and the thumb and index finger should be preserved at almost any cost. In amputating fingers, the head of the metacarpal bone should be preserved, and in general, in the arm, the ideal is to conserve every saveable portion of the limb, and a generous interpretation should be given to the word "saveable."

Leg.

In leg amputations we are on entirely different ground, for prostheses are excellent, and operations should be planned with these in view. Three amputations need consideration.

(i) *The Syme.*

A Syme amputation is to be condemned in the presence of infection. A properly carried out Syme is a satisfactory operation if the stump remains healthy, but the Roehampton experience is that it does not provide a lasting satisfactory

stump; that the average "life" of a Syme is $8\frac{1}{2}$ years, and that patients come gladly to re-amputation. With the passage of time the heel-pad tends to slip laterally, and as the scar is anterior and transverse it is subjected to the piston action of the stump, and in consequence becomes painful, and painful neuromata are common.

(ii) *Below-Knee Amputation.*

The ideal is 6" measured from the inner articular surface of the head of the tibia, though 4" was recently receiving consideration. An anterior flap is used and the scar is got to lie transverse and as far posterior as possible. The flaps and other tissues are cut in accordance with the general principles given earlier. Equilateral flaps are strongly condemned.

(iii) *Above-Knee Amputations.*

The essentials of a poorly covered flap being again observed, the femur is sectioned 10" from the tip of the great trochanter. The amount of femur left should not exceed 12". Small anterior and posterior flaps are cut to leave the scar transverse and about $1\frac{1}{2}$ " above and posterior to the level of bone section. If the stump is too long, it should be re-amputated before fitting a prosthesis and if it is shorter than desirable, the more essential is it to have it poorly covered. In high amputations demanding a tilting-table fitting, amputation should be at the level of the lesser trochanter or even the greater trochanter, rather than that a disarticulation should be performed.

