having the uterus in the grasp of the hand, and the benefit of an examination if it goes suddenly out of the hand.

Mole.—2 cases; one large mass of hydatid; this was treated with chloroform and dilatation with Barnes's bags; in the other a large quantity of mole and a child healthy at full time.

Monstrosities.—8 crania or spinal bifidas; one small one was cured by iodine, but the child did not grow up; 8 cases of harelip more or less severe; 5 anencephalous, one lower part of belly wanting, one contents of belly hanging out at umbilicus, one no anus or rectum, meconium-like discharge from bladder. Other small things a few, such as want of small parts, supernumerary fingers and toes, etc.

Premature Births.—126 reckoning from sixth month onward; 63 dead some time before labour. Very few lived any length of time. These were accounted for in many ways, separation of placenta, albuminuria, scarlet fever, pneumonia; in most the reason was not known, or at any rate not well known. A few cases from syphilis; my experience in our country district is that two or three children are born prematurely and decaying, after that a fairly healthy family, and continuing healthy. Two women aborted about the fifth month, one from pneumonia, the other from albuminuria; the latter died.

Rupture of Uterus.—Three cases. One, multipara, aged 40. Seven years from last birth. Strong, little fat woman; occipito-posterior position; tried forceps twice and failed; then turned, and forceps to head. Head extraordinarily elongated from great pressure; placenta came easily, and uterus contracted fairly. Complained of great pain, and looked like sinking after labour, but lived six days. A rupture of two or three inches across the neck of uterus, beginning on left side. The second case was a very strong, little stout woman; very hard os, for which I tried chloral, and very hard labour; died almost immediately after labour was completed. No instruments used. *Post mortem*, small tears were found in the peritoneal coats, some deeper, and half-pint of blood in the peritoneum. The third case was the sister of last and of the same build; she was a multipara, and was in the hands of my assistant till her labour, which was severe, suddenly ceased. The head was well down, instruments were easily applied, and she was delivered easily and quickly; the placenta came away soon and no more haemorrhage than usual occurred, but she looked prostrated, which we were inclined to think might be from the severe protracted labour. She died next day. There was a large rupture across the uterus about the neck. In none of these cases was I aware that rupture had taken place till the *post-mortem* examination. Fortunately for me, I never had much difficulty in getting a *post-mortem* examination; in many places there is no chance. It requires training, and might be overcome to a far greater extent, and with great advantage to the doctor.

Indentation of frontal bone has happened five times; it always happens in difficult long forceps cases. It did not happen in the same woman twice, though three of the cases had come through severe labours. In one of the cases I heard it take place just as the head engaged in the pelvis. This was her first living child, evidently a smaller child; the first, severe, long forceps; second, forceps and craniotomy; third brought on premature labour at eighth month, but a breech presentation, and failed to save child. I corrected the second last indentation by pressure round the edges of the depression, and reported it in the BRITISH MEDICAL JOURNAL. It went into its place with a sound like a dislocated bone. It is worth trying, and I think a small, finely-made screw, which could be screwed into about the centre of depression and lift a little would almost certainly correct it at the moment, and save operation which is sometimes done for it. I have had a small screw made for the purpose by Young, of Edinburgh, which would do it, I feel certain, combined with pressure at the edges, and take no more room in the midwifery bag than a needle.

Rupture of Perineum.—I have had no case of rupture into the bowel, perhaps half a dozen cases reaching to about $\frac{1}{2}$ in. or so from the anus. Three or four of these were treated by stitching, not very successful in some, others left alone, keeping the patient on her side to avoid discharges. There were many slighter cases, which are unavoidable with the best management, and are, I believe, best left alone. One can scarcely tell to look at the parts after that such a thing had happened. It is now a good many years since I have seen one of these worst cases, but would now stitch, avoiding including the skin. I saw the benefit of this some years ago when I was asked to take a case in hand, in which a distinguished surgeon had failed by paring and stitches including skin. I could not coax her to go to hospital again, and made a good job by flap-splitting, which is easy and sure, and no loss of tissue.

Does support of the perineum help to prevent rupture? I believe keeping back the head long and strongly would, but no other help. I used to keep back the head, pressing forwards slightly. Long ago some of my patients told me they felt great relief from support of the bowel, and for some years I used to press on the anus and pretty strongly forwards. I decided after a good long experience that this

was dangerous, because it presses out the head—just what one is trying to avoid.

The deaths in these nearly 6,000 cases were 28; 8 from previous existing disease, 1 from putrid child (from which I suffered myself, never being able to see her again), 1 erysipelas, 2 pneumonia, 1 measles, 1 some peritonitic mischief (being her second premature labour), 2 scarlet fever. Four of these gave birth prematurely.

From septic fever, 1 real case of puerperal fever, 5 pelvic or peritoneal mischief, 2 cases of phlebitis coming on after the patients were out of bed and well, 4 cases of convulsions, 1 almost dead already from general paralysis, 4 from scarlet fever, 1 embolic clot of brain on the second or third day. In 5 of these 28 deaths forceps were used, 2 requiring great help; the others were easy cases. One of these 5 cases was a primipara aged 45 years, who but for religious feelings and anxiety to have a living child should have been relieved sooner by craniotomy. In only 4 of these cases could the doctor's finger or anything about him be blamed, and I believe this is pretty much the history of midwifery in Scotland; at any rate in a neighbourhood like mine, where it is the rule to have the doctor. It should be the same in England if the work were in the hands of the doctor.

Abortions have been numerous and many more were never heard of. A woman has often told me that she had several mishaps. In many cases pretty severe haemorrhage occurred, but none died from it. The treatment has been to do one's best to get the fetus away; in strong women this is often not practicable; giving ergot frequently and temporising, it comes away safely in a day or two. I feel sure there would have been a considerable death-rate if I had followed the advice of some great men, who have advised that a woman should not be left till the uterus is cleared out by the finger, or, if that fails, the curette—a dangerous tool in the best hands.

Nature has provided wonderfully for the safety of woman in her hard hour, we should be careful neither to add nor remove without good reason.

THE EVAPORATION OF CHLOROFORM DURING INHALATION.

AN INQUIRY INTO THE FACILITIES OF REGULATING WITH GREATER ACCURACY THE STRENGTH OF THE VAPOUR EVAPORATED FROM WOVEN FABRICS.

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THE process of dropping chloroform upon a piece of lint and allowing the patient to inhale from this, has the appearance, at first sight, of being extremely simple; but this is, however, an entire misapprehension, for the complexity of physical conditions is great, and gross fluctuations are liable to occur in the vapour which is yielded in accordance with apparently negligible, and certainly neglected, changes in conditions. Ignorance in regard to this subject has led to the adoption of various phrases and ideas which have no real signification, and are mainly due to wrong inferences regarding the relations which exist between the quantity of chloroform poured out and the strength of the vapour which is afforded. Thus such general injunctions as the giving of "plenty of chloroform" or "plenty of air" arose doubtless in relation to some definite procedure, but that they cannot involve that which they imply is evident from a consideration of the overwhelming preponderance of air over vapour which must of necessity exist even in the case of the most concentrated non-lethal mixtures.

The method is one of "unknown percentages," for no attempt is thus made to gain a knowledge of the strength of the vapour administered; but means—certainly very imperfect ones—are adopted to regulate the strength of the vapour according to the clinical indications of the patient under observation. These means consist principally of approaching or withdrawing the mask from the face, pouring or dropping out a greater or less unmeasured quantity of chloroform, or by an intermittent administration; and naturally these procedures, even in capable and experienced hands, leave a great deal to be desired.

This method must, however, be considered seriously and in detail, for whatever may be the ultimate fate of more exact mechanical appliances, it will survive for use under certain eventualities, for it is a ready means of producing anaesthesia when no other materials are available except the ever-ready bottle of chloroform.

Various attempts have been made, more particularly by Lister,¹ to estimate the concentrations of chloroform vapour which are afforded by the simple appliances in general use. Into these calculations there necessarily entered too large an element of conjecture to enable the investigators to work out such a delicate problem with success. Mr. W. Legge Symes² has recently brought a more exact method to bear upon the subject, and his estimations are, therefore, of great interest, but it is evident that a more extended analysis is possible and desirable. The investigations which I have carried out have aimed at the consideration of the more important physical conditions which attend the evaporation of chloroform, and they have led to the conviction that not only chloroform, but other anaesthetic vapours also, may be far more accurately adjusted to the patient's requirements by simple means than has been generally surmised.

The apparatus which I employed for these investigations consisted simply of a bellows arranged to simulate human breathing, and provision was made for regulating the volume of air sucked in and expelled at each expansion and compression; as the pace at which the air currents moved depended upon the rate of driving the appliance, it was an easy matter to counterfeit any required depth or force of respiration. The estimation of the amount of the chloroform vapour taken up by the aspired air was carried out by the densimetric method introduced by Waller and Geets,³ a densimeter bulb being interpolated for this purpose in the suction stream between the chloroform and the bellows, a by-pass being provided for the passage of the expelled air back to the chloroform.

The terms "suction" and "expulsion" will be applied in this paper to the two phases of the artificial respiration, and the terms inspiration and expiration to the corresponding processes of human respiration only.

A. CONSIDERATIONS OF TEMPERATURE.

Naturally the starting point of observations of this kind must be a consideration of the reciprocal relations which exist between temperature and evaporation. Quick and slow volatilization are the result of high and low temperatures respectively, and hence arises a difficulty which is well recognized in every method proposed for regulating anaesthetic vapours. An illustration of this important relation is given in Table I, which shows the percentages which may be presumed to be yielded when the conditions of evaporation are the same in each case, and are of such a nature as to afford a non-saturated vapour.

TABLE I.—Vapour Yielded under Conditions of one-tenth Saturation at Various Temperatures (deduced from Snow's Estimations).⁴

Temperature at which Evaporation takes place.	Percentage of Vapour.
24° Centigrade	2.2 per cent.
19° "	1.6 "
14° "	1.1 "
9° "	0.8 "
4° "	0.6 "

This table serves to accentuate the importance of considering the temperature at which the chloroform is evaporated, and of the rapid cooling which it undergoes during evaporation by reason of the abstraction of "latent heat" from it by its vapour. In order to arrive at an estimation of the extent of the fall of temperature which actually occurs during inhalation I have made some observations by placing a sensitive thermometer in close contact with a suitable material to which chloroform was applied under conditions which admitted of its rapid evaporation by artificial ventilation with the bellows on the one hand and by natural respiration on the other.

TABLE II.

Conditions of experiment: The thin bulb of the thermometer was interwoven in the strands of a section of a domette diaphragm, through which the air currents were alternately sucked in and expelled.

0.5 c.cm. of chloroform was applied about the bulb upon one quarter of the domette.

The expansion capacity of the bellows was set to 360 c.cm., and 30 alternate expansions and compressions were made per minute. (This frequency is a common one under chloroform anaesthesia.) The human respiration was timed to the same frequency and adjusted as nearly as possible to the same volume.

Room temperature 15° C.

Seconds.	Aspirations.	Temperature under	
		Artificial Respirations.	Natural Respirations.
0	—	15° Centigrade	15° Centigrade.
5	—	11° "	11° "
10	5	5.5° "	8° "
15	—	2.0° "	6° "
20	10	0.0° "	5°* rises
25	—	—2.0° "	
30	15	—3.0° "	
35	—	—3.5°* rises	

*The last figure in each column indicates the point at which the temperature commenced to rise on account of the exhaustion of the chloroform.

It is apparent from this and numerous similar experiments that human respiration affords a contrast with artificial respiration in two particulars, for evaporation is relatively accelerated by it, and the fall in temperature is considerably diminished; consequently a corresponding equalization of evaporation will take place. These results occur as a consequence of the warmth of the exhaled air, which tends to prevent excessive cooling. This constant factor also bears an important relation to the initial atmospheric temperature, for within the range included in my observations (namely, 14° C to 24° C.) the final temperature in every case of human respiration lay within the limits of 5° and 7° C., independently of the initial temperature. Thus the expired air plays an important part as a temperature regulator, and this material consideration obviously discounts to a great extent the supposed importance of the effect of the temperature of the external air.

There exists further a very practical way, not of preventing fluctuations of temperature, but of evading their effects, for the anaesthetic effect produced upon a person must depend not so much upon the vapour tension of individual inspirations, but upon the mean tension of a number of inspirations, mainly on account of the comparatively large atmospheric contents of the lungs with which the individual respirations become merged; when, therefore, small quantities only of chloroform are evaporated at a time—that is, within the duration of a few respirations—the resulting anaesthetic effect will bear a relation to the mean of the descending scale of tensions at which the consecutive inspirations are made. A similar consideration applies to the mitigation of the somewhat raised mean vapour tension in hot weather. In such circumstances the whole of the liquid is evaporated more rapidly, and at a higher mean vapour tension, but provided that the same number of respirations be allotted to each application of chloroform as suffices for its complete evaporation during cooler weather, then at all temperatures a given quantity of vapour is mixed with a given quantity of air and the resulting average in the lungs will be almost the same, despite its having been inhaled in each case at different concentrations per respiration. To sum the matter up, it can be stated that a required anaesthetic effect may be perfectly maintained in spite of temperature variations, provided that definite and small quantities of chloroform be applied at definite intervals of respirations. When large quantities of chloroform are being evaporated a prolonged and slow series of temperature changes may result, and will no doubt give rise to varying tensions which will be sufficiently long continued to induce corresponding general anaesthetic effects.

Before leaving this subject it is necessary to consider

how far the results obtained with an artificial respiration apparatus deviate from those occurring under conditions of similar but human respirations. From the data at my command I should judge that the mean percentage values given in the succeeding sections, which are derived from artificial respirations, require, at a maximum computation, an addition of one-third of their magnitude to bring them into conformity with clinical conditions.

NOTE.—The percentages given in the tables which follow represent as nearly as possible those derived from a mean temperature; such values were arrived at by performing a suitable number of aspirations to each estimation, and by varying this number in accordance with the magnitude of the aspirations.

B. PHYSICAL CHARACTERISTIC OF FABRICS.

It appears to be a prevalent idea that anything which will absorb chloroform will also serve as a vehicle for its administration. This may in a sense be true, but that

Fig. 1.—a, Lint; b, domette.

fabrics cannot be employed indiscriminately is illustrated by the consideration of the following particulars:

1. *The absorbent quality of fabrics* was investigated by adding a small quantity of an aniline dye* to the liquid chloroform, which left in consequence a permanent stain upon the fabric from which it was evaporated. The accompanying photographs (Fig. 1) portray the stain which results from the application of 30 drops of dyed chloroform to domette and to lint respectively, the reproductions being made on precisely the same scale. The domette is a good example of a fabric which is

absorbent in the sense that it promotes a capillary spread of the chloroform, so that a large area is covered with a thin but fairly evenly distributed film of the anaesthetic. The lint, on the other hand, does not tend so much to promote capillary spreading, the total surface covered being smaller, and it acts more like a sponge will act in taking up a mass of chloroform which largely accumulates at the point of application; such spreading as does occur is very imperfect, for it takes place (as the photograph shows very well) by selection along the less numerous and more fluffy threads of the warp. It is obvious that a material which best promotes a rapid and even distribution is to be selected for clinical use, not only on account of the evenly-conducted evaporation that it involves, but also because a required evaporating surface can be produced with the smallest quantity of chloroform. Of the materials which I have investigated domette best fulfils these conditions.

The same method of investigation shows that for a given material the amount of chloroform applied is a rough guide to the extent of surface covered; thus for amounts of 5, 10, 15, and 30 drops each, the averages of the corresponding areas stained in three different fabrics vary in the ratio of 1.0, 1.8, 2.8, and 4.7. The same quantity, however, applied to different materials, as already implied, yields very different results; thus, for instance, the average areas produced in the case of domette, lint, and linen towel respectively, vary in the ratio of 3, 1.8, and 1. The details of these experiments are given in Table III.

TABLE III.—Showing the Extent of the Spreading of Chloroform in a Single Thickness of Different Fabrics (50 Drops of Chloroform to 1 Cubic Centimetre).

Number of Drops.	Domette. sq. cm.	Lint. sq. cm.	Linen Towel. sq. cm.
30	96	64	36
15	61	36	20
10	38	25	12.5
5	23	12	7

The spread of the chloroform may, perhaps, be most accurately controlled, and certainly an even distribution best ensured, by applying chloroform in an appropriate number of separate patches of a few drops each, and under certain conditions this method is, in my experience, the most convenient.

The result of folding a fabric several times is this: the mass of liquid applied becomes divided up between the folds, so that the spread is restricted in proportion as the folds are numerous. Manifold materials are only requisite when it is desired to hold in suspension a large quantity of fluid.

2. *The Texture of Fabrics.*—A loosely-woven fabric, such as domette, will allow the respirations to pass through its

Fig. 2.—S is a flat porcelain slab upon which the flannel (f) is spread. On top of the flannel is laid a glass plate (g), out of the centre of which a circular hole has been cut in order to expose the required area. A glass disc (d), from the centre of which an aspirating tube (t) is led off, is supported at a definite distance above the flannel, which is saturated with chloroform.

meshes with great facility, and air thus passing through a fabric comes into intimate contact with the chloroform it holds in suspension, and so has the opportunity of taking up a high percentage of vapour. This aspect of affairs may be illustrated by means of the arrangements for obtaining estimations of vapour which is illustrated and described in Fig. 2, but for this special purpose the porcelain slab (s) was removed from under the fabric, which was then supported merely by a large retort ring, so

* Erlich's "Dahlia" answers well for this purpose.

as to leave an open air space beneath it. The percentages thus obtained are given in Table IV.

TABLE IV.

In this case the chloroform was submitted to one phase only of aspiration—that is, the suction phase.

Volume of bellows expansion 360 c.cm., frequency 30 per minute.

Area of fabric = 200 sq. cm.

Distance of disc from fabric 5 mm.

A single fold only of each fabric was used.

Linen Towel.	Fine Flannel.	Domette.
Per cent. 2.7	Per cent. 3.4	Per cent. 4.3

There existed a fairly free passage for the air between the disc and the fabric, and in the case of the towel it is probable that, on account of its relative impermeability, it took this course almost entirely. In the case of the flannel and domette, however, the raised percentages can only be due to the fact that a greater or less proportion of air passed directly through them.* This "breathing through" is an important and an insufficiently recognized factor in most of the usual methods of administering chloroform, especially those for which a frame or mask is employed; the closer the fitting of the edges of the mask to the face the greater the proportion of air which is breathed through it, and hence the greater the effect which is produced. In many practical methods of administering chloroform, as also in the foregoing experiments, the process of inhaling is a mixed one of "breathing over" and "breathing through" a chloroform surface, but in order to arrive at a precise knowledge of the physical conditions which control evaporation, I found it necessary to dissociate these two processes, and study them separately.

C. EVAPORATION BY CURRENTS OF AIR PASSING ENTIRELY OVER THE SURFACE OF THE CHLOROFORM.

The experimental inquiry into this branch of the subject was conducted by means of the appliance shown in Fig. 2. This arrangement may be taken to reproduce the clinical conditions in which an impervious material, such, for instance, as a folded towel, is roughly adapted to the facial contour and the tidal air propelled in and out between the parallel surfaces of the material and the face. The results obtained are concisely summarized in Tables V and VI.

TABLE V.

Volume of aspiration, 360 c.cm.

Frequency of aspiration, 30 per minute.

Conditions of aspiration, alternate suction and propulsion.

Ten aspirations made before taking each estimation.

Height of disc above flannel, 1 cm.

Temperature of room, 17° C.

The area of fabric which was submitted to experiment was governed by the size of the hole in the glass plate which covered it.

Areas of Chloroform Surfaces in sq. cm.	Diameters of Surfaces in cm.	Percentages.	
		Calculated from the Ratio of the Perimeters	Observed.
26	5.75	0.98	0.95
68.6	9.35	1.60	1.55
196	15.80	2.70	2.70

In the above table the "observed" percentages were obtained in the usual way with the densimeter, and from the highest of these, namely, 2.7 per cent., the values for the other areas were calculated in the ratio of the circumferences of those areas, and these values are tabulated in the column headed "calculated."

The observed results are contrary to expectation, for it has usually been assumed that the vapour evolved is directly proportional to the surface exposed to evaporation, whereas these figures show a

* When air is forced entirely through a fabric, then the closer its meshes the higher the percentage; very close woven materials under such clinical conditions would, however, involve laboured breathing.

direct proportional relation between the vapour and the circumference of the area, or, what amounts to the same thing, the square root of the area. Of course, this relation has probably an application to these special conditions only; in fact, they are partly the result of the, from a physical point of view, exceptional condition of an alternating current of air, the expelled air being partly confined in the apparatus and re-aspirated; but I have also found good reason to believe, from experiments under simpler conditions of aspiration, that the air absorbs a considerable part of its charge of vapour at its first point of contact with the chloroform, and that hence the extent of the periphery of the moistened surface exercises a considerable control upon the total amount of vapour taken up.

TABLE VI.

Average temperature, 13.5° C.

Area of chloroform surface, 200 sq. cm.

Frequency of aspiration, 30 per minute.

Type of aspiration, alternating suction and propulsion.

Vertical Measurement of Air Space.	Volume of Aspiration.		
	550 c.cm.	360 c.cm.	160 c.cm.
4 cm.	Per cent. 0.85	Per cent. 1.0	Per cent. 0.90
3 "	1.85	2.4	2.40
2 "	1.75	3.1	3.60
1 "	1.60	2.7	4.75
The flannel folded into light contact with the disc around the aspiration tube	—	5.5	—

In Table VI are found several minor variations, which are, perhaps, open to further investigation; but, at the same time, there are certain main conclusions to be drawn which have a practical application. In the first place, a withdrawal of the mask from the face entails a dilution of the vapour which affords the greatest contrast in the case of small, weak inspirations, but during strong ones the relation of distance to percentage is of less importance. In the second place, very slight contact between the surfaces may result in the production of a very powerful vapour. Thirdly, the variations of the force of respiration produces an effect which must be extremely embarrassing from a clinical standpoint when the adaptation of the surfaces is fairly close, but this variation becomes practically non-existent when the distance of the mask is considerable.

The surface of 200 square centimetres which was submitted to these experiments is larger than is practically convenient, and hence, with a smaller surface, the distant position at which the respiratory fluctuations in percentage tend to disappear can only be attained at the expense of too great a dilution of the vapour, and it is my practical experience that a surface of this kind requires to be held in close apposition to the face to induce anaesthesia with sufficient expedition. It is my view—which, I believe, is common to other anaesthetists—that in the administration of chloroform as well as of other anaesthetics a higher strength of vapour is required to induce anaesthesia within a workable period than is required to maintain it; so that anaesthesia may perhaps be favourably maintained by this method, more especially in the case of superficial operations, provided the correct distance be properly gauged. The production of a constant extent of evaporation surface is, however, a difficult problem, and as this must in any case involve the application of a considerable quantity of chloroform, we have to contend with the additional complication of variable temperature effects. In short, I cannot conceive of any practical means by which an impervious material can be adjusted so as to regulate the vapour with any degree of accuracy.

There exist several well-known methods which involve the use of impervious fabrics. The six-fold towel (the Edinburgh method) comes under this category; this has been regarded as an essentially "open method," but it appears to have been employed in such a fashion as to obtain the maximum of vapour available; thus Lister⁵ who for many years advocated this procedure directed that the towel should be held as close to the face as could be comfortably borne. The method contains no

intrinsic theoretical advantage, but at the same time, it is interesting to observe that the abnormal quantities of chloroform employed, "unmeasured and unstinted," do not tend to the production of abnormal percentages, they merely extend the period of efficiency, for the tendency to an extension of surface by absorption is already small in a single fold of towel, and it is further limited, in the manner already explained, by the employment of several folds.

A single layer of lint is fairly pervious to air, but a double layer is practically impervious, and such a double layer is commonly employed in close contact with the face. This form of mask certainly possesses the advantage that it is readily reversible, and small quantities of anaesthetic may be frequently applied on alternate surfaces, and in this way the danger of an accumulation of unevaporated residues is obviated.

Any closely applied moderately impervious chloroform mask which encloses a considerable space is undesirable, and the various forms of "cones" are on this account open to objection. With such appliances during periods of very weak breathing or temporary closure of the glottis, the heavy chloroform vapour is liable to accumulate in the space and produce a very strong atmosphere, and sudden and disastrous consequences may follow the restoration of normal respirations. It is under such conditions of an enclosed and concentrated atmosphere that a sudden deep gasp becomes dangerous; whereas, under the more usual and safer conditions, a rapid flow of air thus produced tends, if anything, to the production of a diminished vapour tension.

D. EVAPORATION BY CURRENTS OF AIR PASSING ENTIRELY THROUGH A PERVIOUS SURFACE.

The experimental study of this subject is simplified by the fact that the air is excluded from entering under the edges of the mask and so the factor of distance from the face which was so important in the last section does not form a complication; the theoretical consideration of the subject is, however, somewhat involved on account of the rapid revolution of air currents which must take place within the dome of the mask, thus entailing to a certain extent, a simultaneous process of breathing "over."

In Fig. 3 is shown the apparatus which was used for this series of experiments and it is sufficiently explained by the description appended to it. In these experiments I have taken a certain area of domette and caused the air currents to pass through it, but it would appear from Table VII that it is a matter of comparatively little moment what the actual total area of this material may be; this will not appear strange when it is remembered that the air stream must be distributed to the same extent as the chloroform.

TABLE VII.—*The Percentages obtained from Aspiration through Different Areas totally wetted with Chloroform.*

Conditions of experiment: The area of domette which was submitted to experiment was governed by the size of the holes in the glass plates between which it was enclosed.

Volume of aspiration (remaining constant), 360 c.cm.

Frequency of aspiration, 30 per minute.

Type of aspiration diphasic (alternate suction and propulsion).

Room temperature 15°C.

Area of Surface (in sq. cm.).	Percentages obtained.
69	3.8
50	3.7
25	3.3

Such differences as are shown in the table are simply explained when we consider the pervious areas of fabric as apertures, the size of which will naturally determine the rate of flow of the air at that point; the smaller surfaces, therefore, will promote more rapid air currents, which will take up less vapour in their passage. The interesting conclusion to be drawn is that a restriction, within limits, of the size of a pervious mask does not involve a corresponding restriction of the vapour, and is useless therefore as a precautionary measure, a conclusion which is entirely in accord with my practical experience.

When, however, only a limited part of the domette is wetted with chloroform, we may regard the whole air

stream which passes through the domette diaphragm as being split into two portions, one of which consists of pure air and the other containing a definite proportion of vapour. Provided that the meshes of the fabric are not blocked up by too copious a supply of chloroform, then the two streams must follow the law which governs the flow through simple apertures, and hence the percentage of

Fig. 3.

f is a glass funnel of which the stem has been cut off; into its smaller end is fitted an aspiration tube (a) by means of a cork (c). The edges of the larger end are ground flat, and they support the perforated glass plate (p'). Between p' and a similar plate (p) the domette (d) is enclosed.

vapour in the mixture will, theoretically, be directly proportional to the extent of surface which the chloroform is spread over. This proposition was put to an experimental test by dividing a circular area of domette into separate sectors by means of ribs of a non-absorbent material, after the plan shown in Fig. 4, the smallest sector of which measures one-fifteenth of the whole pervious surface.

TABLE VIII.—*The Percentages obtained from Aspiring Air through Domette only partially wetted with Chloroform.*

Conditions of experiment: The proportion of the area wetted with chloroform was defined by radiating ribs of "batiste."

Volume of aspiration (remaining constant), 360 c.cm.

Frequency of aspiration, 30 per minute.

Eight aspirations performed to each estimation.

Room temperature 15°C.

Total area exposed to the air stream by the holes in the glass plates, 65 sq. cm.

An excess of chloroform was applied in each case.

Proportion of Area Bearing Chloroform.	Percentages.		Values (Theoretical) which are in Direct Proportion to the Areas Concerned.
	Double Aspiration (Suction and Propulsion).	Single Aspiration (Suction only).	
One fifteenth	0.65	0.33	0.3
Two fifteenths	1.10	0.65	0.6
Four "	1.75	1.20	1.2
Eight "	2.60	2.35	2.4
Twelve "	3.40	3.50	3.6
Fifteen "	4.10	4.30	4.5

It is seen from the above table that under the more simple experimental conditions of intermittent suction only (the propelled air being allowed to escape) the percentage of vapour obtained is very nearly directly proportional to the fraction of the total area which is moistened with chloroform. Unfortunately this relation fails under the test of a double-phased aspiration—alternate suction and propulsion—when the lower percentages are raised in value and the higher lowered. It follows that although a percentage value cannot be assigned in direct accordance with the area wetted, still it is evident that, even under clinical conditions, each section possesses its own definite and ascertainable power of generating vapour.

The effect of altering the force of the air current has been indirectly illustrated in Table VII; the changes in the percentages consequent upon direct variation in the force of the aspiration are given in Table VIII. These changes are seen to be far less in magnitude than those which are found to occur under some other conditions, such, for instance, as aspiration "over" a closely-applied

surface. The reason for this is that all the currents are so spread out and consequently slowed down at the moment of passing through the fabric, that they tend to vary little among themselves in their capacity for taking up vapour.⁶

TABLE IX.—*Showing the Result of Varying the Force of Aspiration.*

Type of aspiration, alternate suction and propulsion.
Frequency of aspiration, 30 per minute.
Temperature of air, 15° C.

Volume of Aspirations in c.cm.	Proportion of Area to which Chloroform was Applied.		
	Entire Surface.	Six Fifteenths.	One Fifteenth.
550	3.30	2.00	0.75
360	3.75	2.45	0.70
160	3.90	2.70	1.00

It is evident from the foregoing considerations that the process of "breathing through" a material affords favourable opportunities of regulating the vapour. This process can be carried out by means of any of the various frames in general use which can be made to fit close to the face at their edges with a fair degree of accuracy. The prime necessity is a means of controlling the area wetted, and two ways of effecting this have occurred to me:—

1. The areas may be mechanically limited by some such contrivance as the domette cover shown in Fig. 4, which was used for the experiments already described.* The domette is in this case adapted to clinical purposes by being sewn on to a sheet of non-absorbent material, such as batiste, and it can thus be used on a suitable frame. Each section of domette is entirely separated from its neighbours, and even when thoroughly saturated with chloroform there is no possibility of an overflow taking place. Under conditions of proper adaptation to the face, approximate values of percentage of vapour may be assigned to each division, according to the estimations given in Table VIII, the proper correction being supplied for human respiration (see Section A); but inasmuch as it may be difficult without undue pressure to ensure in all cases such a close apposition that no air enters beneath the mask, the values must be regarded as the maximum obtainable. It should, however, be noted that the existence of a slight adventitious entry of air in this way has not the same significance when the air way of the inhaler is superabundant (as in this case) as it would have if a more restricted air channel were provided. However, on account of this and other more or less important sources of variation, I cannot regard this method as affording reliable percentages, which in my experience to be of value must be

* Messrs. Allen and Hanbury are making an approved pattern of his cover.

absolute and invariable; otherwise it is better to be content with clinical indications, and with such guides the cover provides valuable possibilities of limiting, and of increasing and decreasing, the strength of vapour with great precision, for it provides a complete immunity from the mischievous effects of an accumulation or a widespread diffusion of chloroform. The exact amount of chloroform applied to the smaller sections is not very material, but when using a large area it is important to apply only just sufficient to cover it, so that the strong vapour is evolved for the shortest possible time. In the case of the largest section fifteen drops are sufficient, and this proportion serves as a guide to the supply required for the other sections. The supply of chloroform must be renewed at fairly regular intervals of respirations and the correct interval may be at once ascertained by running a finger over the surface, for the chloroform is so cold that its disappearance is readily remarked. The administration is conducted upon the general principles which relate to chloroform inhalation, but it is worthy of remark that it is frequently not necessary to exceed wetting one half of the total area in order to induce anaesthesia, and that the smallest section is

sufficient to maintain it in the case of many superficial operations.

2. The areas may be controlled upon an undivided fabric according to the relation which it has been pointed out exists between the amount of chloroform, measured in drops, and the resulting spread of the chloroform. The simplest method, so far as manipulation is concerned, is to apply the anaesthetic at a single spot, and to regulate the number of drops according to the effect required. It is, however, doubtful whether the proportion between the number of drops and the area produced can be relied on during rapid evaporation by inhalation, but it may perhaps form the basis of definite procedures which may be worked out according to individual inclination; the procedure which

Fig. 4.—The shaded part represents domette sections which are sewn into a groundwork of batiste cloth. The diameter of the circle is 11 cm., and the four sections represent roughly estimated maximum percentage values as follows: 0.8, 1.5, 2.3, and 3.5 per cent.

I have myself adopted, and which I find capable of very delicate adjustment, is as follows: On a medium-sized mask as many as four patches of chloroform, of 5 drops each (40 drops to 1 c.cm.), may be applied without their coalescing, and there are thus provided four grades of strength of vapour, intermediate grades being introduced if required by diminishing the number of drops in one group. In the case of an adult breathing an average depth of respiration the process works out as follows: The mask is imagined as divided into quadrants, and intervals of six respirations are decided upon; the administration is commenced by applying two drops to one quadrant, increasing the amount to five drops in successive applications; the next thing is to repeat the process in addition on a second quadrant, ultimately applying five drops to each of three quadrants and if necessary four. Once anaesthesia has been induced in this way it is maintained by omitting groups of drops as rapidly as possible, until one group is found sufficient, when further attenuation of the vapour is aimed at by gradually increasing

the intervals of respirations if possible up to ten. A slight amount of skill enters into this method in rapidly pouring out and enumerating the drops, and also an element of judgement in estimating the depth of the respirations, for although deep respirations, which are generally forcible, tend to take up a diminished percentage of vapour, this tendency is insufficiently marked to prevent a more rapid evaporation, so that a shorter interval has to be allowed, that is, about four respirations; and, conversely, as many as eight or nine shallow respirations may be required to make up an interval. However, these adjustments are made with little difficulty, for a change of anaesthetic state, which is conveniently gradual, will call attention to the requirements. Chloroform given in this way is administered under the most favourable conditions regarding distribution, quantity, and temperature variations, and it is capable of the most delicate double adjustment by drops and intervals; in fact, once a routine is established, the vapour is practically continuously constant in strength; thus, with the artificial respiration apparatus I obtain values of 3.15, 3.2, and 3.2 per cent. at the seventeenth, twenty-third, and twenty-eighth respiration respectively.

As regards the frame employed, I find a Schimmelbusch with a pear-shaped rim to be the most readily adaptable. An efficient drop bottle is also an essential, and nothing is better than a glass bottle with a grooved stopper affording a rapid succession of individual drops, of which between 40 and 50 go to make up 1 c.cm.

The above procedures, derived from experimental work and clinically confirmed, I believe to be the best suited to the administration of pure chloroform.

I may shortly state that these principles relating to the process of "breathing through" apply with added force to the use of diluted chloroform, as in the form of A.C.E. mixture; it is only necessary to employ a cover of four-fold gauze divided into four equal divisions and to proceed on an assumed efficiency of one-third of that of pure chloroform—that is to say, using three times the quantity. With ether anaesthesia may be very readily maintained in this way without undue waste (it may, indeed, be induced with a little perseverance), and the excellence of the type of anaesthesia thus obtained deserves detailed comment; however, clinical considerations are somewhat outside the scope of this paper, and cannot be further discussed. I think I have said enough to show how the principles can be extended in many directions.

In this paper I have considered the administration of anaesthetics from one point of view only—that is, that of the regulation of the vapour. This is an essential part of the anaesthetist's business, and I am inclined to think that it is the most essential part, for no accurate or intelligent appreciation of the physiological effects of anaesthetics is possible without it.

I have to conclude with an expression of thanks to Professor Vaughan Harley for kindly allowing me the use of his laboratory.

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⁴ John Snow, *On Anaesthetics*, p. 33. ⁵ *Loc. cit.* ⁶ Levy, *Lancet*, May 27th, 1905, p. 1415.

LANDRY'S PARALYSIS.

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THE case of which full details are given below was from a clinical standpoint a typical instance of Landry's disease. The motor symptoms, it should be noted, were those of a gradually-ascending flaccid palsy, and these mounted to so high a level that on the eleventh day of illness ocular movements were impaired. Thereafter the symptoms gradually retrograded. Throughout there were no sensory symptoms nor any incontinence of faeces or urine, and eventually recovery was complete.

W. H., aged 30, waiter, admitted to the Westminster Hospital on August 3rd, 1904.

Previous History.—Had had syphilis at 24, and thereafter thorough and prolonged treatment. Had had no other previous

serious illness. Had not drunk to excess. Usually smoked 1 oz. of tobacco a day.

History of Present Illness.—Quite well up till eleven days before admission; at that time the legs began to get weak, and in three days' time loss of power in them was complete. For three days before admission patient had been gradually losing power in the hands, and for one day had had double vision and difficulty in swallowing. For first three days of his illness patient's legs had ached. There had been no numbness or paraesthesia, and no headache or backache. The bowels had been constipated, and there had been some difficulty in starting micturition. There had been no incontinence.

State on Admission.—The patient was well nourished and of a good colour. Mentally he was markedly intelligent. Special senses of smell, taste, and hearing were normal. Vision of R. eye $\frac{2}{3}$, of L. $\frac{1}{3}$. Visual fields were normal. Optic discs normal.

Outward movements of both eyes were incomplete in range. There was no nystagmus. The left pupil was a little larger than the right, and both were almost immobile to bright light. There was slight ptosis of the left eyelid. There was no obvious affection of parts supplied by the fifth and seventh nerves. The left half of the soft palate drooped more than the right and moved less completely.

The tip of the tongue on protrusion deviated to the right and its lateral movements were feeble. There was slight difficulty in pronouncing the lingual and guttural sounds.

There was no movement at any of the joints of the legs or feet, with the exception of the right first metatarso-phalangeal joint; here the big toe could be feebly flexed and extended. The leg, if lifted and dropped, fell flaccidly and presented no passive resistance to the movement of its joints.

The patient could not sit up, though the abdominal muscles could be felt to contract on his attempting to do so. The movements of the upper extremity were very feeble. The thumbs and little fingers could not be approximated, and the fingers scarcely abducted or adducted.

Flexion of the head was very feebly performed, but lateral movements of the head were fair. Respiratory movements were good. The anal sphincter was very lax.

There was nowhere any sign of tremor, fibrillation, or rigidity. The various muscles felt flabby, but did not seem to be wasted. The co-ordination of movements, where any could be performed, was good.

There were no sensory changes, objective or subjective. No reflexes could be obtained from the lower limbs. The abdominal, cremasteric, and epigastric superficial reflexes were normal, as were also the triceps and supinator jerks. There were no trophic or spinal changes.

A faint apical systolic murmur was heard, but otherwise the thoracic and abdominal organs presented no abnormal physical signs. The spleen was not enlarged. The urine showed no abnormality.

Progress.—Up to August 8th the movements of the limbs and trunk remained much as described above. On that day the emotional movements on the left side of the face were noted to be not quite so good as on the right side; forced movements were equal on the two sides. The ptosis of the left eyelid was more pronounced. The abdomen was rather distended. On August 10th the hand grips were slightly stronger and speech a little more distinct. The patient complained less of diplopia. The left pupil reacted to light more rapidly than the right. Both pupils just reacted to painful stimulation of the skin of the neck, but did not accommodate. The triceps and wrist jerks were less brisk than before. The abdominal, cremasteric, and epigastric reflexes could not be elicited.

By August 15th the patient was again able to swallow solids, the ocular movements were better, and the hand grips still stronger.

On August 25th slight power of flexion and extension at the ankles returned; the legs, also, could be slightly flexed upon the trunk and abducted and adducted.

By September 3rd both pupils reacted well and equally. There was no ptosis, and ocular movements were through a normal range, but there was a little nystagmus on extreme lateral movement. There was no further complaint of diplopia. The patient could sit up in bed, using his arms to heave himself up. All movements at all the joints of the legs could be feebly performed. The knee-jerks and ankle-jerks seemed normal. The flexor response was present on both sides.

Result.—By September 17th the patient was walking with the help of sticks, and shortly after left the hospital.

The temperature had been observed to be elevated to 99.4° F. on the day of his admission, thereafter it had been normal. On August 9th the electrical reactions were reported as showing some diminution to faradism, and on September 14th some increase. There was no reaction of degeneration. Drug treatment had consisted in the administration, during the early stages, of potassium iodide. From August 21st onwards massage and electricity were used. The patient was last seen in May, 1904, when he had almost wholly recovered. He could then walk perfectly well on the flat, but experienced a little difficulty in going upstairs.

REMARKS.

The etiology of those cases of acute ascending palsy which appear to their various reporters to justify the title