(16)

A Lecture

ON

THE ADMINISTRATION OF CHLOROFORM TO MAN AND TO THE HIGHER ANIMALS

Delivered in the Physiological Laboratory of the University of London on October 13th, 1903

BY

AUGUSTUS D. WALLER, M.D., F.R.S.

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GENTLEMEN,—On previous occasions, when it has fallen to my lot to replace one of my colleagues in this lecture-room, I have invited you to inspect the work that happened to be in progress in the laboratory, and to the best of my ability I have explained the origin, the state, and the purpose of what you have seen. I shall again employ my lecturer's hour in this way, and lay before you as fully as possible in the time the state of the case concerning the experimental study of anæsthetics, which, as some of you know, has been a principal subject of study in this laboratory during the past year. And whereas last summer I dealt at length with purely scientific aspects of the problem, I shall to-day confine myself to the practical side, which is the direct logical consequence of the scientific side—that is to say, that I shall deal with the administration of chloroform to man and to the higher animals.

Some preface is, however, necessary. Although these lectures are addressed to students of second degree possessing already such primary information as may be acquired in the regular medical curriculum, it has happened that non-medical persons, unacquainted with the first rudiments of medical study, have obtained permission to be present. To anyone who has attended the lectures and practice of the laboratory during the past year it will, I hope, be matter of surprise that two intelligent young ladies should have come here for many days and have neither seen nor learned anything to give them pause from rushing into print with a horrified condemnation of physiology and of physiologists. If the two young ladies under whose name the publication entitled "Shambles of Science" has appeared, came simply to get "copy" the case is easily understood; but I am unwilling to believe this; and, indeed, the case looks to me much more like that of a pair of very ill-advised busybodies supporting each other through a trying ordeal for the sake of what they imagined to be an errand of mercy. I am sorry they came. I should have told them or any other non-professional women that they had better not come to such lectures, for they would run the risk of being misled and pained by experiments where no suffering to living animals was caused. Indeed, one would look very much askance at the young woman who should be able to look on while an animal was, as she imagined, undergoing torture.

For the naked details of even a properly conducted vivisection, ignorantly considered, as must be the case if they are considered at all by an unprofessional person, appear revolting—so do the details of a surgical operation or of the slaughter of an animal for food, or of the proceedings in the dissecting-room and the post-mortem room. The minute and graphic account of such details by ignorant women is from every point of view mischievous and deplorable, and I very much regret that these two unfortunate ladies should have obtained the opportunity to torment themselves and their readers by their conscientious misrepresentations. Physiologists, when vivisection is necessary, do not take either pleasure or pain in its naked details, and they systematically take due precautions to fully anæsthetise animals required for experiment. The incredible motives sometimes attributed to physiologists by well-meaning people and the unlimited adjectives and substantives by which they are held up to public reprobation can only be left to the antidote of their own excess. It is really labour lost to be constantly pleading "not guilty" to this, that, or the other quite outrageous statement; we can only wonder that well-meaning people can so quietly harbour such infamous thoughts.

Nor have we failed to question our own conscience. We well know that physiologists are subject to the common laws governing the human mind and that habit must tend to engender inattention and that inattention would be cruelty. We are on our guard against our own inattention, but knowing that we are human we do not resent as indignantly as might be expected of us the reminder to be on our guard that is contained in the denunciations of our critics. We also know that there is evil in the appearance of evil, that things right and proper in themselves but offensive of appearance ought not to be exposed. And if exposure by even competent authority must offend and injure the imaginations of ordinary men and women, how much more injury and offence to the public mind will be committed by incompetent and self-deluded women who have entered what is to their minds nothing more than a chamber of horrors, where in reality the "quivering flesh" and "palpitating heart" and "tortured nerves" are more often than not only the living parts of dead animals, and where in any case an animal, even if alive, has been absolutely deprived of sensation. When one attempts to realise what kind of images must hold possession of an ignorant, prejudiced, and sensitive person—man or woman—who has seen without understanding, he ceases to wonder at bad language, yet what can he hope to say that shall reach the mind of the deluded fanatics whose pity has been fanned to hatred by agitators. And can it be expected of us that we should say anything at all to persons who can employ sensational literature to poison the wells of human sympathy.

In this laboratory—and no doubt in others—our very first concern is to administer anæsthetics properly when anæsthetics are required. And I make the deliberate statement that ·· imals in this laboratory are anæsthetised with as great certainty and accuracy as are the patients in any hospital in the United Kingdom. Can it be necessary to tell you that we do not juggle with bottles of "colourless and odourless" liquid as imagined and stated by the two ladies who have visited these "shambles"? You shall see for yourselves what takes place out ide the lecture-room whenever it is necessary to anæsthetise an animal. I have chosen cats for my demonstration, since the demeanour of these animals is most familiar to us.

Cat No. 1 was anæsthetised three hours ago by the inhalation of chloroform and air at 2 per cent. and has during the last three hours been maintained in profound anæsthesia in a mixture of between 1 and 1·5 per cent. I now pass it round the class, so that you may all assure yourselves of its state, and when it returns to the lecture table it will be left to recover. Its recovery will take place in not less than half an hour nor more than three-quarters of an hour, and will, I believe, be complete within an hour. By complete recovery I mean that state in which the cat will drink milk and purr, and a saucer of milk is therefore placed by the cat as its normal test. You will have understood from this illustration that complete anæsthesia can be, and regularly is, established as long as necessary for the purpose of experiment; and you will hardly need to be told that the anæsthesia can be kept up by a continuous administration, or strengthened if it should at any moment appear to be weakening.

On Cat No. 2 you will see how anæsthesia is induced, and Cat No. 3, which has been left upon the operation table for another purpose, will serve to let you see how the anæsthesia has been maintained throughout an operation. Cat No. 2 has been borrowed for the purpose of this lecture on the understanding that it shall be returned intact. It is to be fully anæsthetised by a mixture of chloroform and air at 2 per cent. according to the regular custom of the laboratory. The induction of complete anæsthesia will take not less than five minutes nor more than ten minutes, and the recovery will be complete in half an hour. I shall also show you how we verify that the mixture is at or about 2 per cent., and in so doing I shall have demonstrated to you how we ascertain the percentage of any unknown mixture of chloroform and air.

Cat No. 3, now upon the operation board, is dead, having just served for an experiment in which we measured the amounts of chloroform inspired and expired (1) during a normal induction of anæsthesia by chloroform at a low percentage and (2) during a normal production of death by chloroform at a high percentage. Throughout this experiment we have observed and recorded the respiration and the blood pressure, the percentage of chloroform in the inspired and expired air, and the total volume of air breathed per minute.

The results of the experiment are contained in the record now on the cylinder (Figs. 1 and 1A) and in the numbers written on the blackboard (*vide infra*). The remainder of my lecture will be occupied by an explanation of the exact manner in which these several observations have been carried out, and by a very few concluding remarks concerning the anæsthesia of the human subject.

Experiment made on Oct. 13th on a Cat weighing 2·9 kilos.

Part I.—Induction of complete anæsthesia by nine litres of chloroform and air at 2·7 per cent. $CHCl_3$ in 7 minutes 40 seconds. The frequency of respiration was 70 per minute with an average depth of 16 cubic centimetres per respiration.

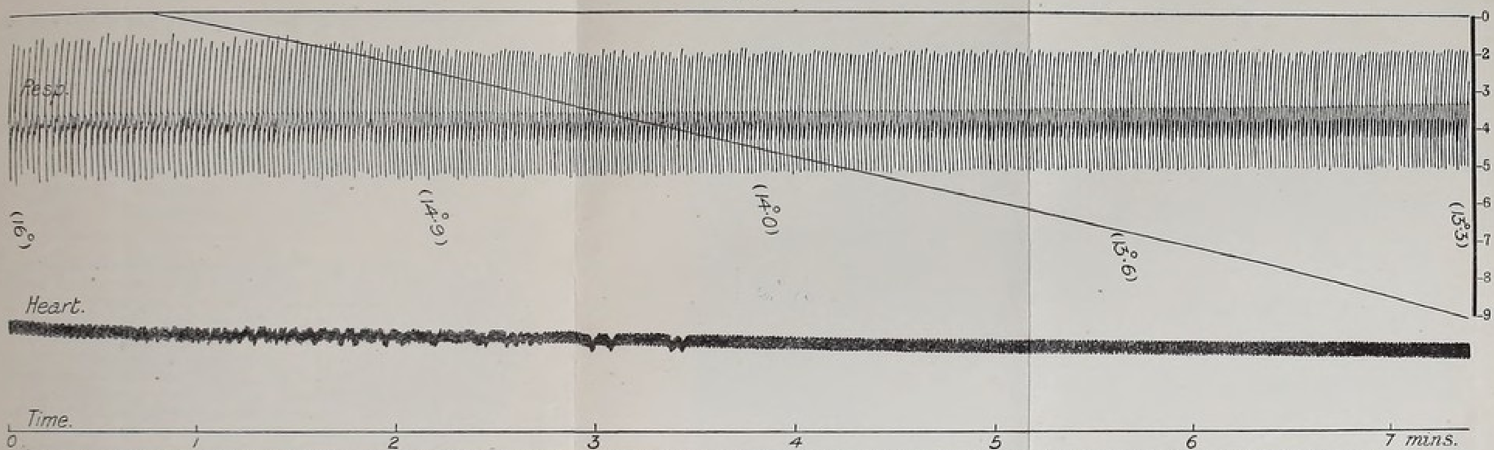
Inspired ...	2·7 per cent.,	i.e., 243 cubic centimetres of $CHCl_3$ vapour in 9 litres of air.	
Expired ...	2·1 ,,	,, 189 cubic centimetres.	
Retained ...	0·6 ,,	,, 54 ,, ,,	(or 0·27 gramme).

Part II.—Death by two litres of chloroform and air at 14·2 per cent. in three minutes.

Inspired ...	14·2 per cent.,	i.e., 284 cubic centimetres of $CHCl_3$ vapour in 2 litres of air.	
Expired ...	7·9 ,,	,, 158 cubic centimetres.	
Retained ...	6·3 ,,	,, 126 ,, ,,	(or 0·63 gramme).

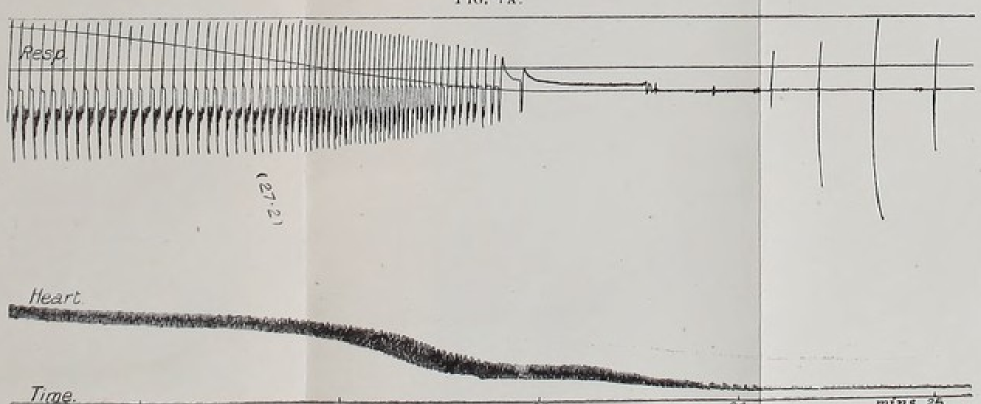
Of course, such an estimate of the total quantity of chloroform absorbed during a given period would be more immediately satisfactory if that total quantity could be directly measured. But I have ground for concluding that the result obtained by calculation from the percentage of given samples and the total volume of air used, does actually represent a close approximation to such total quantity. In a series of trials made last year of the delivery by an apparatus recently proposed for clinical anæsthesia I measured (1) the total volume of air drawn over a weighed amount of chloroform; (2) the loss of weight of the chloroform; and (3) the percentage of chloroform in the issuing air by densimetry. The percentage, as given by the densimeter sample, is very nearly

FIG. 1



Experiment of Oct. 13th, 1903 (Part 1). Cat weighing 2·9 kilos. Anæsthesia by chloroform vapour at 2·7 per cent. (The oblique line across the tracing is the gasometer record of the volume in litres of air breathed by the animal. The numbers in brackets signify the temperature of the chloroform.)

FIG. 1A.



Experiment of Oct. 13th (Part 2). Death by chloroform at 14·2 per cent.

that afforded by the quotient of total chloroform divided by total air :—

1 Total of air in litres.	2 Loss of $CHCl_3$.	Percentage calculated from (1) and (2).	3 Percentage by densimetry.
25·2	2·38 (476 c.c.)	1·89	1·90
12·6	1·56 (312 c.c.)	2·48	2·30
8·4	1·29 (258 c.c.)	3·07	3·10

All three cats have gone through the proceeding you witnessed in the case of the borrowed cat—it is our regular laboratory procedure for cats, dogs, rabbits, rats, mice, pigeons, and frogs—and the differences of susceptibility to chloroform exhibited by these various animals are so small that we are justified in translating to the human subject the knowledge we have acquired at their expense. The animal is placed under a glass bell jar through which chloroform and air of known percentage are pumped. The pump is one originally devised by Professor R. Dubois of Lyons for the anæsthetisation of the human subject and has proved very valuable as a laboratory instrument. The only objection to its use is, as far as I can ascertain, its price—£20 ; but as a matter of fact as a laboratory instrument it is commercially economical. We have never lost an animal by chloroform since it has been in use, and the amount of chloroform employed in the laboratory has been comparatively small ; the certainty and safety with which anæsthesia has been induced have very materially lightened the preparations for an experiment ; it has enabled us to keep animals in complete anæsthesia for as long as 12 hours.

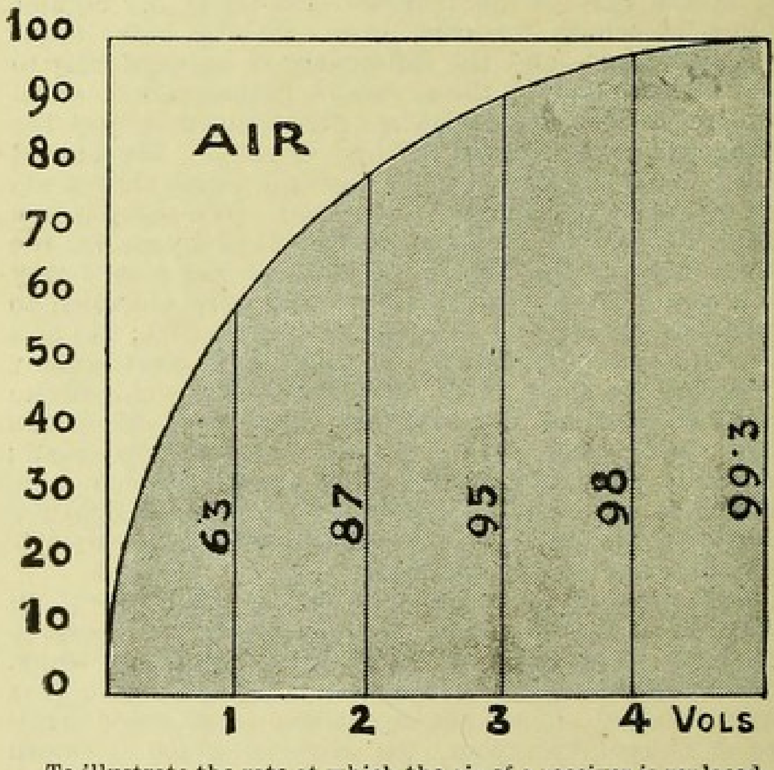
At each stroke of the pump four and a half litres of air are delivered at the outlet and an equal amount is drawn in at the inlet. The inlet is by an open bottle into which each stroke automatically delivers 0·3 cubic centimetre (five minims) of liquid chloroform, equivalent to 90 cubic centimetres of chloroform vapour, the whole of which is drawn into the pump at one stroke and delivered at the next stroke. Thus at one, two, three, or four strokes per minute the delivery is 4·5, 9, 13·5, and 18 litres per minute of a 2 per cent. mixture of chloroform and air, and whether the pump is worked quickly or slowly (within reasonable limits) the percentage remains at this figure, which is the maximum value afforded in the automatic working of the apparatus (but can be lowered to 1·6 and 1·2 per cent. by turning a cam or raised to between 3 and 4 per cent. if demanded).

The nominal delivery of this (or of any other apparatus) is readily tested by the densimetric method.[1] A 250 cubic

[1] Proceedings of the Physiological Society, 1903.

centimetre bulb, previously counterpoised on a balance, is placed upon the delivery tube, filled with the mixture, closed, and replaced upon the balance. It is found in the case now before us that an addition of 22 milligrammes is required to the counterpoise—i.e., that the percentage of chloroform in the sample is 2·2. The data upon which this method of estimation is based are as follows. Each cubic centimetre of chloroform vapour is four milligrammes heavier than one cubic centimetre of air, so that 2·5 cubic centimetres—i.e., 1 per cent. in the 250 cubic centimetres flask—are ten milligrammes heavier. Ten milligrammes signify, therefore, 1 per cent. and 22 milligrammes 2·2 per cent.

FIG. 2.



To illustrate the rate at which the air of a receiver is replaced by chloroform mixture of any given strength. When the receiver has been traversed by once, twice, three times, &c., its volume of mixture, the contents = 63 mixture + 37 air; 87 mixture + 13 air, &c. The mixture is practically at its full strength when the receiver has been traversed by five times its volume.

It will be worth while to realise the way in which the percentage of chloroform in a reservoir rises to that of a chloroform plus air mixture delivered through it. Fig. 2 will help you to do so. You may see from it that a reservoir through which once, twice, thrice its own volume of a mixture has been slowly passed, contains a more dilute mixture at 0·63, 0·87, 0·95 of the percentage of the original mixture, and that when five times the volume has passed, the percentage in the reservoir is practically equal to that of the supply. For a bell jar of 30 litres supplied by a chloroform mixture at 2 per cent. at a rate of 30 litres per minute (seven strokes per minute of the Dubois's pump are more than sufficient for this) the percentage in the jar at the end of the one, two, three, four, and five minutes will be 1·26, 1·74, 1·90, 1·99, and 1·99. And as regards the densimeter bulb by which we just sampled the percentage of supply, a single stroke driving ten times its volume of gas through the bulb is obviously more than sufficient to give a full strength sample of mixture in the bulb.

Let us turn our attention to the results obtained on Cat No. 3. It was first anæsthetised under the bell jar; a cannula was then placed in the trachea connected by a tube with a Woulfe's flask containing chloroform so that the inspired air was charged with an unknown amount of chloroform vapour by which the anæsthesia was maintained. This is the ordinary laboratory method of keeping up anæsthesia but it is a dangerous method and one that is not used in this laboratory except for the actual study of chloroform; we prefer ether for ordinary use. In the present case, the purpose of the experiment being to get at the percentage and amount of chloroform administered, a densimeter bulb is placed on the inspiration tube and the total amount of air inspired is measured by a gasometer. In the present case the total amount of air inspired was nine litres (in seven minutes 40 seconds) and the percentage of chloroform vapour in that air was 2·7. The total volume of chloroform vapour taken into the lungs was, therefore, 243 cubic centimetres, or rather more than one gramme of fluid chloroform

Was all this chloroform vapour retained? Probably not, or rather evidently not, since the expired air of the animal smelt strongly of chloroform. How much then was the amount of chloroform rejected in the expired air? To ascertain this was a rather more troublesome matter; a Chauveau's valve (Fig. 3) connected with two densimeters, one on the inspiratory and the other on the expiratory side, was ultimately found to answer the purpose extremely well. The flaps of the valve act perfectly with inspirations and expirations ranging from 10 to 1000 cubic centimetres and the "dead space" of the apparatus is as small as possible, so that the column of air moved to and fro with respiration is not much greater than that of the large air passages. We have to prevent any condensation of water vapour from taking place in the expiration bulb. To this end it is placed in a metal chamber kept at between 40° and 50° C. by an incandescent lamp and to keep things equal the inspiration bulb is placed by its side in the warm chamber. A slight increase of weight (1·3 milligrammes per 1 per cent.) in the expiration bulb by reason of the CO_2 expired is either allowed for or estimated separately. Its accurate determination might be of importance in low percentage estimates; but in high percentage estimates, like the present the error due to this source may be disregarded. Thus 5 per cent. of chloroform is signified by 50 milligrammes and 4 per cent. of CO_2 is signified by 5·2 milligrammes; for ordinary purposes then it is well to

FIG. 3.

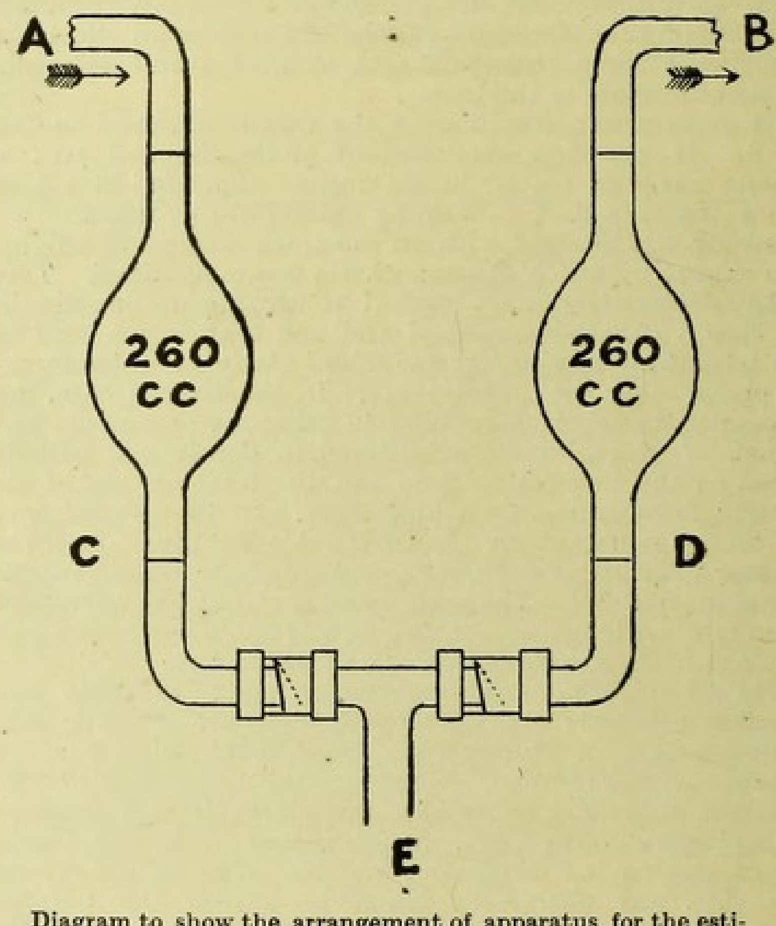


Diagram to show the arrangement of apparatus for the estimation of chloroform in the inspired and expired air. Tube A is attached to a chloroform flask, tube B to a gasometer. Tube E of the Chauveau valve is connected with the trachea. Two densimeters are attached to its inspiratory end C and to its expiratory end D. (The warm jacket enclosing the densimeters is not shown.)

subtract five milligrammes from the weight of the expiration bulb as the average value of the CO_2 weight in expired air.[2]

We are now in a position to draw up a more complete balance-sheet showing the pulmonary absorption of chloro-

[2] A respiratory quotient of 0·9 has been assumed in the calculation of the densimetric value of CO_2 in expired air.

form during a given period, the excess of income over output representing what has been retained in the body during that period. In the case before us the percentage of chloroform in the expiration densimeter was 2·1, or 189 cubic centimetres of chloroform vapour were rejected in the nine litres of expired air. So that we have :—

Chloroform inspired	...	243 cubic centimetres.		
,, rejected	...	189 ,, ,,		
,, retained	...	54 ,, ,,		(= 0·27 gramme).

That has been the story of the induction of profound normal anæsthesia by chloroform vapour at a rather high, but not in itself a dangerous, percentage. The amount of chloroform rejected was greater (and of that retained was smaller) than I have seen in other similar experiments. I attribute this to the character of the breathing which was rapid and shallow—above 60 per minute.

Turn now to the second part of the experiment, when the cat was deliberately sacrificed by the inhalation of chloroform at a high percentage, all arrangements being made as before to record the movements of respiration and the blood pressure, the percentage of chloroform in the inspired and in the expired air, and the total volume of air breathed. Death occurred, as in the great majority of such cases, by failure of respiration, followed by failure of the heart. The percentage of chloroform as given by the inspiration densimeter was 14·2, by the expiration densimeter 7·9 (corrected for 2 per cent. of CO_2 determined volumetrically). The total volume of air breathed was two litres in three minutes, when respiration ceased. We have in this normal death by chloroform at a high percentage the following result.

Chloroform inspired	...	284 cubic centimetres.		
,, rejected	...	158 ,, ,,		
,, retained	...	126 ,, ,,		(= 0·63 gramme).

Commentary is hardly necessary ; the facts speak for themselves. In Part I. an animal was fully anæsthetised by chloroform absorbed at the rate of 27 milligrammes per minute. In Part II. the same animal was killed by chloroform absorbed at the rate of 210 milligrammes per minute.

For the sake of comparison with the results of to-day's experiment I have set out for your inspection the principal data of a similar experiment made two days ago on a dog.

Experiment made on Oct. 11th on a Dog weighing Seven Kilogrammes.

Part I.—Induction of complete anæsthesia by 8·5 litres of chloroform and air at 3·1 per cent. of $CHCl_3$ in four minutes 30 seconds.

Inspired ...	3·10 per cent.	......	263·5 cubic centimetres.	
Expired ...	1·86 ,,	......	158·1 ,, ,,	
Retained ...	1·24 ,,		105·4 ,, ,,	(= 0·527 gramme).

Part II.—Death by eight litres of chloroform and air at 13·2 per cent. $CHCl_3$ in three minutes.

Inspired ...	13·2 per cent.	1056 cubic centimetres.	
Expired ...	6·66 ,, ...	533 ,, ,,	
Retained ...	6·54 ,,	523 ,, ,,	(= 2·615 grammes).

One accident, and one only, has occurred in this laboratory since the procedure which you have just witnessed has been regularly adopted. It was not due to the procedure but to its absence. The accident was so strikingly instructive that I shall give you an exact account of how it occurred and of what we learned from it. The animal—a cat—had been fully anæsthetised and transferred to the operating table when the operator was called to some other more urgent matter. On his return he found the animal undergoing artificial respiration which failed to restore it. Death had taken place. The animal had shown signs of recovery from the anæsthetic and had been re-anæsthetised by "*a few drops of chloroform on a cloth*" which had caused sudden arrest of the heart and of respiration. The accident was obviously a case of early cardiac death of the kind well known to physiologists and dreaded by surgeons. I believe that it can only occur when a sudden wave of concentrated chloroform vapour reaches the lungs and pulmonary blood, and I adopted the following device to ascertain whether the conditions under which the accident had just taken place were compatible with the reason given.

An open glass tube was placed between the teeth of the dead animal and connected with a densimeter bulb and an aspirator that drew two litres of air through the bulb in two minutes. A few drops of chloroform were poured on a cloth which was wrapped round the head of the animal as previously for the production of anæsthesia. The percentage of chloroform found in the air aspirated through the densimeter was found to be 11·2. A second trial with the cloth more loosely applied gave the percentage 2·5. A third experiment with the cloth held away from the head of the animal gave the percentage 1·2. The tube was then removed from the animal and clamped under a tripod on which the cloth was placed. Chloroform was then put on the upper surface of the cloth drop by drop and the aspirator A was set going for two minutes so as to draw two litres of air *plus* chloroform vapour. The sketch (Fig. 4) will show you exactly how the cloth, the tube, the densimeter, and the aspirator were disposed. The distance between the cloth and the mouth of the tube was three inches, the temperature of the room was 18·5° C. (65·3° F.), and the barometer stood at 768 millimetres of mercury. The percentage by the densimeter was 0·8. In subsequent trials the percentage was 0·7, 1·0, 0·8 with the cloth loose over the tripod, and 1·9 with the cloth more closely wrapped round it. I now understand as I never understood before how it is that an "open method" involving the administration of "plenty of chloroform with plenty of air" is a relatively safe method. It is relatively safe because under the ordinary physical conditions of the method, with due skill and unflagging watchfulness on the part of the administrator, the amount of chloroform vapour in the mixture of chloroform and air offered to inspiration is as a rule between the desirable limits of 1 and 2 per cent. It must be obvious to you that this simple apparatus places in your hands the means of studying the kind of chloroform percentage offered to the inspiration of a patient by any of the various masks and other apparatus that are in use for the chloroformisation of the human subject.

FIG. 4.

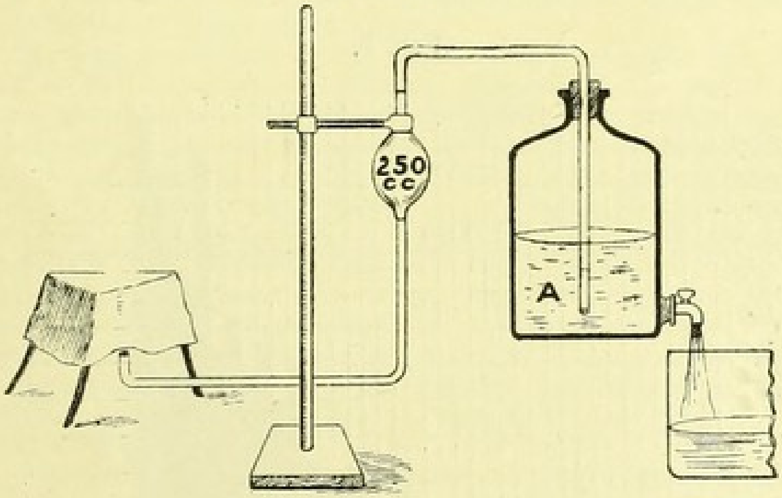


Diagram of the apparatus referred to in the text for the rapid estimation of chloroform percentage in air beneath a cloth or mask.

The relative danger of a closely fitting mask, even when the chloroform is given drop by drop, cannot but be evident to you. The reason of the relative safety of the Edinburgh practice—plenty of chloroform with plenty of air—will be no less intelligible. Lawrie, the most convinced and persistent advocate of this method, gives "doses" of chloroform that are enormous, but he is careful that the amount he uses shall not reach the patient's lungs. There is no special virtue in any mask; one towel is not more dangerous than another, nor is there any good reason why it should be preferred to a piece of lint. That method is safest which best secures that the patient shall continuously inspire a mixture of chloroform and air with not less than 1 per cent. and not more than 2 per cent. of chloroform vapour in the mixture.

I have naturally and almost without noticing the transition passed to the last and most important head of my lecture—

the application of our laboratory knowledge acquired on animals to clinical practice applied to ourselves. Not much time remains to me for all there is to say; perhaps I may be permitted to deal more fully with the many questions that come up for answer under this head on some future occasion.

The words "and the higher animals" have expressly formed part of the title of this lecture. Under "clinical practice" I include "veterinary practice." Personally I should be almost as willing to expend thought and money to insure the safe anæsthesia of a favourite animal that required operation as to insure that of an unknown man, woman, or child. Happily, however, there is here no antagonism of interests nor protection of commercial privileges at stake;

Fig. 5.

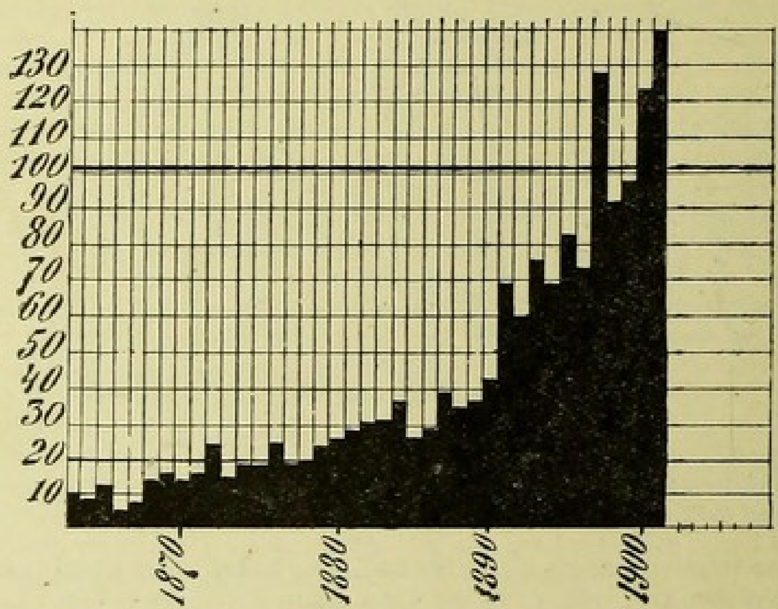


Diagram of the annual numbers of "deaths from anæsthetics" in England in the years 1863 to 1901 constructed from the returns of the Registrar-General.

here anything benefiting a dog or cat must also benefit man, and anything benefiting the man must also benefit his friends among the animals. Men have paid and are still paying a heavy price in return for the boon of anæsthesia conferred upon them 60 years ago by Wells, Morton, Soubeiran, Flourens, Simpson, and Snow. The annual returns of the Registrar-General exhibit the picture shown in Fig. 5 of the increasing price paid in human lives from 1863 to 1901. It is an unnecessary price, inasmuch as the chief reason of its payment consists in the ignorance of the most elementary principles of anæsthesia. Anæsthetists explicitly assert that they are not acquainted with chloroform in arithmetical terms, as 1, 2, 3, and 4 per cent., and that they judge of its power solely from its clinical signs and symptoms.

Experience is, no doubt, the great teacher. The empirical anæsthetist of to-day who has witnessed the clinical signs and symptoms presented by patients in danger of death, or actually put to death, under his method of administration is, no doubt, a less dangerous administrator than the instructed scientist quantitatively acquainted with the power and properties of anæsthetic agents. But the scientific man does not desire to trespass upon the domain of the practical anæsthetist; he only wishes to bring to the common melting pot his own contribution of experience in the belief that it will prove to be an important ingredient of the practical knowledge of future anæsthetists.

You may have heard about that worthy nurse who did not hold with "those new-fangled thermometers" but preferred to regulate the temperature of the bath by the colour of the baby's skin. She was probably a better nurse than some of her younger sisters—better acquainted with thermometers than with babies—not perfectly sure perhaps about Fahrenheit and Celsius—but she is certainly a still better nurse when she has learned to count on a bath-thermometer. Chloroform anæsthesia is of greater importance to us all, and even an experienced anæsthetist is a safer anæsthetist if he can count the chloroform he gives us, and if he is accustomed to think about chloroform in concrete numbers, instead of judging by symptoms only and recognising (or not) that a danger signal is in sight.

To return for a moment to the death-rate diagram. The unsifted figures of such returns are not, I am well aware, unimpeachable scientific evidence of actual numbers of deaths directly caused by anæsthetics. The numbers may be too high or they may be too low, they may include cases not caused by anæsthetics but that have occurred from other causes during anæsthesia; or they may fail to include actual cases of death really caused by anæsthetics, but certified—and quite honestly certified—as caused by that disease for which the services of the surgeon and of the anæsthetist had been invoked. And this remark is applicable to continental as well as to English returns. I think that the returns are, however, sufficiently voluminous to be amenable to the "law of large numbers" and to justify us in regarding the actual figures, inclusive of their plus and minus errors, as fairly representative of the state of the case as regards the death-rate by anæsthetics in past years. The figures are at least arranged by unprejudiced machinery, and I cannot but regard as disingenuous the assertion that such figures are worthless and the demand for their detailed analysis. Detailed analysis is impossible and even if possible would be misleading, for if faults of commission might be detected, faults of omission would be beyond correction. It can only be in a few cases that analysis and criticism are possible. I quoted such cases belonging to the period 1896-7 in a presidential address to the Section of Anatomy and Physiology of the British Medical Association held at Montreal six years ago, and I will again quote from the year that has just elapsed two cases which, with full knowledge of the details of both cases, I characterise as unjustifiable accidents directly due to the maladministration of chloroform. The first case occurred in London and the second in Germany.

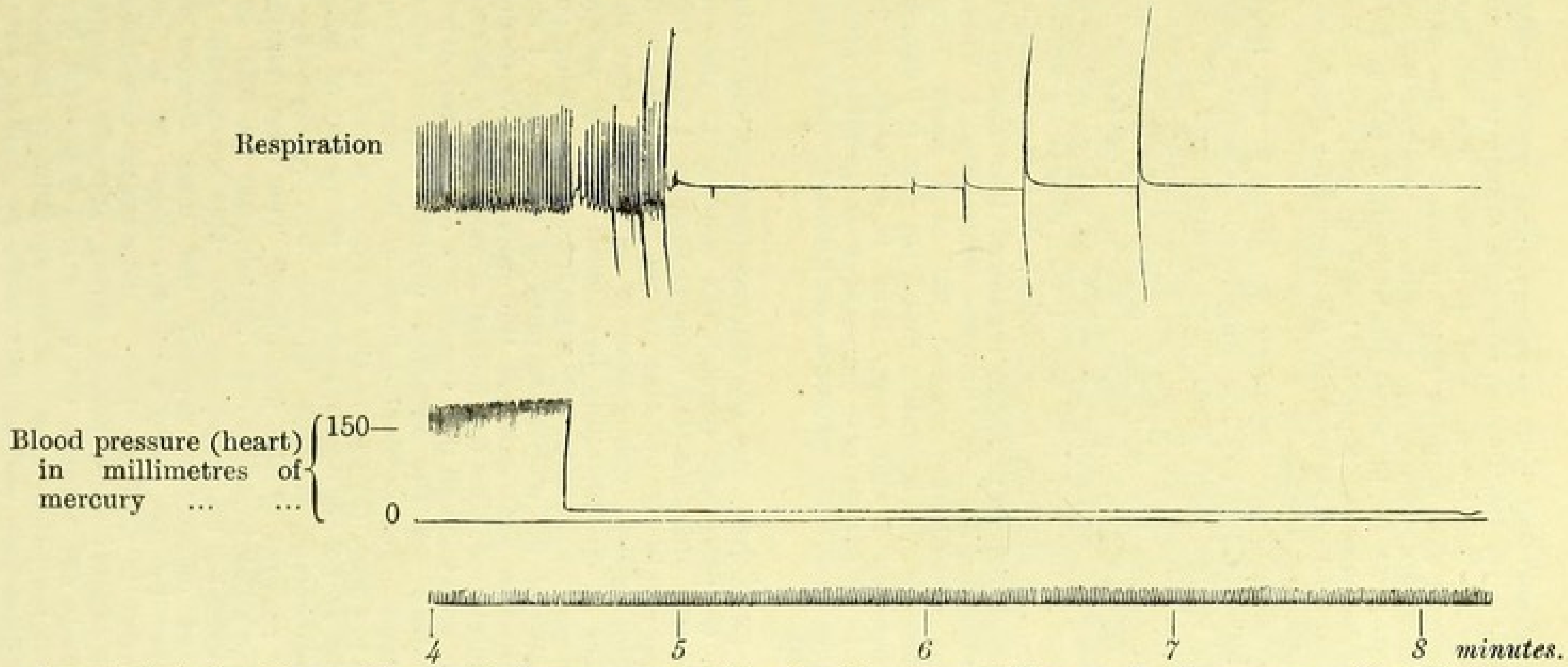
CASE 1.—A healthy, powerful man went to the out-patient department of a London hospital to have a piece of glass removed from his hand, was chloroformed by the "towel method" by the dresser in charge, and could not be brought round. The verdict returned at the coroner's inquest was "Death by misadventure."

CASE 2.—A young woman went into hospital to be operated upon for appendicitis. After due preparation and the patient being in an otherwise healthy state, chloroform was administered by the Esmarch method. Within a few minutes her heart stopped. The statement made in the medical certificate was "Death by syncope."

Both of these most lamentable accidents, which occurred during the last year in the limited circle of my own cognisance (I was not present), were the direct result of chloroform vapour ignorantly administered. No regard was paid to the concentration of chloroform in the air inspired; it may have reached any percentage short of the saturation point of a solution of chloroform vapour in air at the then room temperature. Presumably a deep breath or two of such a mixture were taken, whether few drops or many of liquid chloroform had been dropped on the towel in the first case and on the Esmarch mask in the second, and the wave of chloroform to the pulmonary sheet of blood overpowered the heart directly, or at least placed it in that critical state where any, even the smallest, bulbar disturbance from any afferent channel is to be dreaded. They were early deaths by primary cardiac syncope during the period of induction of anæsthesia; their mechanism is illustrated by this tracing of the blood pressure and respiration of a cat that was being anæsthetised by chloroform at 5·75 per cent. (Fig. 6.) Sudden arrest of the heart, causing sudden fall of blood pressure, took place in coincidence with the slamming of a door. I expressly use the expression "in coincidence with" because I cannot be certain that the slammed door was really the cause of the sudden cardiac arrest and I have failed to reproduce the accident in subsequent trials.

In conclusion, let me repeat a statement made five years ago to the Society of Anæsthetists. "The evidence in

Fig. 6.



An early death by sudden cardiac arrest (primary syncope). Cat under chloroform at 5·75 per cent. No recovery possible. The four gasps apparent on the respiratory record are the terminal anæmic convulsions characteristic of a cardiac death. In the human subject they may arouse hope, whereas in reality they are the last sign of life.

point shows that it is necessary, and within reasonable limits of error practicable, to secure dosage in the administration of chloroform and I should like at once to characterise and earmark that argument by the statement that successful chloroform anæsthesia requires the regular respiration of air in which the chloroform vapour is maintained between the limits of 1 and 2 per cent." Nothing has happened within the last few years that should lead me to modify this statement.

The anæsthetics' death-rate as given in the Registrar-General's returns has not diminished. Cases of death in which it has been possible to analyse and to consider details of procedure remain as unpardonable as ever. And I have shown you as clearly as was possible that animals in a physiological laboratory are as a matter of course anæsthetised by chloroform safely as well as effectively.

What is the cause of the greater danger to which men, women, and children are exposed? Is it fear acting upon a nervous system more highly organised than that of animals, or "idiosyncrasy," or "impure chloroform"? These are perhaps contributory causes, but as I know from the experience of the laboratory that 5 per cent. is "dangerous" and between 1 and 2 per cent. is sufficient, I do not think it proper to give importance to possible secondary influences until the principal condition of safety has been secured.

PS. (Nov. 7th).—By the intermediation of my friend Dr. P. M. Chapman and through the courtesy of the surgical staff of the Herefordshire General Hospital I have received an opportunity of applying to the human subject in the operating theatre the method of anæsthesia that the experience of the laboratory has shown to be so satisfactory in the case of animals. Dr. Chapman will no doubt publish his notes of the clinical features of the cases. I may be permitted to state now that the cases were five in number and unselected, that the induction was effected in from six to ten minutes, and that anæsthesia of required depth was maintained for the required periods without untoward symptoms. The nominal delivery of the pump throughout was 2 per cent. (except in the first case, where it was commenced at 1·2 per cent.), and after the period of induction the percentage actually inhaled was reduced by occasional removal of the face-piece. The total duration of the five administrations was 100 minutes, the total amount of chloroform employed was 100 cubic centimetres (= 30 litres of chloroform vapour), the total volume of air delivered by the pump was 1400 litres (30 in 1400 is equivalent to 2·15 per 100). Densimetric determinations of the delivery taken before, during, and after administration came out between the limits of 1·6 and 2·4 per 100. The determinations were made in an ordinary balance with a half-litre bulb and weights made by dividing two-grain slips of metal into eight parts; each eighth part (= a quarter of a grain) was taken as indicating 0·8 per 100. If I should have occasion to repeat such determinations I should prepare weights = one-eighth of a grain to represent steps of 0·4 per 100. For finer determinations it would be preferable to employ a skilled assistant.

On Nov. 16th, by the courtesy of Dr. F. W. Hewitt, and under his responsibility, I anæsthetised four unselected cases at St. George's Hospital by the Dubois's pump. The induction at 2 per cent. was normal and uniform and was completed within the limits of five and ten minutes (except in the case of an infant when the period of induction was between two and three minutes). Anæsthesia of required depth and duration was maintained at 1·6 and 1·2 per cent., with occasional brief intermissions as judged desirable by Dr. Hewitt. The delivery of the apparatus as tested by densimetry immediately before use was as follows:—

Nominal percentage.	Observed percentage (averages of four trials).
2·0	1·975
1·6	1·600
1·2	1·188

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