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On the observation of the
pupil as a guide in the
administration of chloroform.

BY

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On the observation of the pupil
as a guide in the admin-
istration of Chloroform.

*
In the study of the employ-
ment of Anæsthetics in Surgery, the
changes occurring in the size of the
pupil have not, I think, received
the attention they deserve. The
decided variations which take place
in that organ are very remarkable,
yet no definite conclusion has been
arrived at as regards their relation
to the different stages of anæsthesia.
In the chapters on Anæsthetics in
the leading surgical Text-books, the
pupillary phenomena are quite
passed over or are dismissed with
a

a few words. Sir Joseph Lister, in his article in Holmes' System of Surgery, says,¹ -

"The most convenient test of the patient being prepared for undergoing the operation is presented by the eye, not in the size of the pupil, which is inconstant in its indications, but in what is commonly spoken of as insensibility of the conjunctiva."

Erichsen describes the modifications undergone as follows;² -

"The pupil is at first contracted but afterwards becomes widely dilated and insensible to light, and this is a sign that the administration has been pushed to

¹ Vol. III, Page 603.

² Science and Art of Surgery, Vol. I, Page 23.

"to the furthest limits consistent
"with safety, and must be sus=
"suspended till the pupil again
"responds to light."

Gross makes a similar statement;¹—

"In the second stage, which suc=
"ceeds imperceptibly to the first,
"the individual gradually lapses
"into a state of entire uncon=
"sciousness the pulse and
"respiration will diminish in
"force and frequency, and the
"pupil will become notably di=
"lated."

According to the International Ency=
cyclopaedia of Surgery,²—

"At first the pupils are variable
"in their diameter. When
"Anesthesia $\frac{O_2$

¹ A system of Surgery, by Samuel D. Gross, Vol. I, Page 566.

² Vol. I, Page 406.

"Anæsthesia is fully declared the
"pupils are contracted, but if
"the condition of stupefaction
"is carried to the extreme, dilata-
"tion takes place and persists
"till death."

Attention was called to this
subject in 1874-75 by several ar-
-ticles which were published in
the Parisian Scientific journals.¹
The most important of these ap-
-peared

¹
De l'état de la pupille pendant l'anesthésie chirurgicale produite
par le chloroforme, indications pratiques qui peuvent ^{en} résulter; Progrès
méd. Paris 1874, II, 525, par P. Budin. Considérations sur l'état de
la pupille pendant la durée de l'anesthésie chloroformique; Gaz. méd. de
Paris 1874, III, 469, par P. Coÿne. De l'état de la pupille pendant
l'anesthésie chloroformique et chloralique et pendant les efforts de
vomissements; Gaz. méd. de Paris 1875, 45, 67-69, par P. Budin et
P. Coÿne.

appeared in the "Archives de physiologie normale et pathologique",¹ and was entitled "Recherches cliniques et expérimentales sur l'état de la pupille pendant l'anesthésie chirurgicale produite par le chloroforme." In this paper it was asserted that the condition of the pupil offered a reliable evidence of the degree of anesthesia produced by chloroform, and was therefore of value as a guide in its administration. The conclusions formulated were these:—

I. The administration of chloroform causes on the part of the pupil a series of modifications which are in relation with the state

¹

2^e série II, Janvier, par P. Budin et P. Coÿne

state of the sensibility.

II. During the period of excitement the pupil is dilated.

III. That period being passed, the pupil gradually contracts, but is still sensible to excitations.

IV. During the period of profound surgical anaesthesia, two constant phenomena are to be observed in the pupil, (1) absolute immobility, (2) a state of contraction. There is a relation between the absolute insensibility of the patient and the contraction with immobility of the pupil; between the return to consciousness and dilatation with mobility of that organ.

V. The condition of the pupil is therefore able to serve as a guide

guide in the administration of chloroform.

VI. Gradual dilatation of the pupil occurring during an operation indicates that the anaesthesia is less profound, and that the sensibility is returning.

VII. In operations of long duration if it be desirable to have the patient perfectly insensible, the chloroform should be given in such a fashion that the pupils remain constantly contracted and immobile.

VIII. The efforts of vomiting produce dilatation of the pupil, cause the insensibility to pass off, and the patient to awaken: they destroy in part the effect of the anaesthesia.

IX. 

IX. It is important in observing the pupillary phenomena not to confound the true chloroform anaesthesia with the anaesthesia of asphyxia. The latter causes quite different alterations in the pupil.

X. Though the state of the iris is able to serve as a guide for the direction of the anaesthesia it is unable to give warning of the imminence of accidents.

The pulse, respiration and general condition of the patient must also be carefully observed by the chloroformist.

These conclusions were disputed and contradicted by Professor

Professor Schiff of Florence¹ and others² who published quite opposite results, but up to the present date the action of the pupil during chloroform anaesthesia is still undecided, if we can judge by the conflicting statements made by the various authors who have investigated the subject. In reviewing the literature I have only been able to find one article in which the results given by Budin and Coigne are completely agreed with, viz. a paper written in the Polish

¹ Nota sulla pupilla nella narcosi cloroformica; M. Schiff, Imparziale Firenze, 1876, XVI, 363.

² Chloroform and the pupil; W. H. Winslow, Phila. Med. Times, 1876, VI, 270-277. La pupille considérée comme Esthésiométrie, etc., etc.

Polish language by Dr. Storkowski.¹
Professor Westphal² of Berlin, writing
on the subject of the dilatation
of the pupil, caused by any irri-
-tation made before the patient is
deeply narcotised, says, -

"If one make an individual
" unconscious by chloroform, a
" strong contraction of the pupil
" to a pin point is noticed at
" the commencement of the
" same."

Doziel³ states that chloroform at
first induces contraction and
afterwards

¹ *Practyczne wskazówki o zachowaniu się zrenie pod wpływem
środków znieczulających; Gaz. lek. Warszawa, 1876, XX, 289-291.*

² *Ueber ein Pupillenphänomen in der chloroformnarkose; Arch.
f. Path. Anat. etc., Berlin, 1863, XXVII, 409-412.*

³ *Ueber die Wirkung des chloroforms auf den Organismus der Thiere im
Allgemeinen und besonders auf die Bewegung der Iris; Arch. f. Anat.
Physiol. u. Wissensch. Med. Leipz., 1866, 231-415.*

afterwards dilatation of the pu-
-pil. Schläger¹ gives, as
a result of the observation of
one hundred and twenty two
cases at the surgical clinique
in Göttingen, that in the stage
of full anaesthesia, the pupil
was completely contracted in
one hundred and twenty, and
completely contracted with im-
-mobility in one hundred and
nineteen of these

It has always been
difficult for me to determine
the exact moment at which
a patient is sufficiently under
the influence of chloroform for
an

¹ Die Veränderungen der pupille bei Chloroformnarkose; Centralbl.
f. Chir. Leipz. 1877, IV, 385.

an operation to be proceeded with. The sign of abolition of conjunctival reflex action, which is usually relied on, is very variable; in fact in the majority of cases it is altogether misleading. I have also frequently experienced discomfort from the want of a reliable symptom to indicate whether the patient is deeply under the influence of chloroform, — a matter of paramount importance for satisfactory administration. And I have never been able to observe the modifications of the pupil during the different stages of anaesthesia which are described in most of the above-quoted works.

works, vizt. that it is at first contracted then dilated.

The statements of Brudin and Boigne were so dogmatic, and the results of their experiments seemed so exact, as to make the affair appear very simple. I therefore determined to ascertain for myself whether or not they were reliable, and at the same time if possible to form an opinion as to what changes really occurred in the size of the pupil by the action of chloroform.

As House-surgeon in the Royal Infirmary of Glasgow I was in the habit of administering chloroform almost daily: and in January, 1885, I commenced to

to observe and note particularly the modifications in the pupil under its influence. For this I had the permission of my superior, Mr. Clark, for whose encouragement and assistance I am deeply grateful. A year later I had the opportunity of following up my observations by a series of experiments on dogs. The following are the more important details of a few of these observations and experiments:

A. Clinical Observations.

Chloroform was in all cases given on a thin piece of flannel stretched on a light wire mask.

mask; the fluid was poured from a drop bottle and the pupil was kept under observation from the commencement of the administration till complete consciousness returned.

1. J. B. act. 11; Vertebral abscess.

The pupil, which was moderately wide before commencing, dilated to its fullest extent during the first few inhalations. It continued in this state for a few minutes and the patient after struggling and moaning a little became gradually quiet. The conjunctival reflex being already suspended the operation was commenced, but at the first insertion of the knife the boy shewed signs of pain and

and the incision was therefore delayed while the chloroform was further pushed. In about four minutes from the commencement of the administration the pupil began to contract and soon reached a very small size. The operation was then resumed the patient lying perfectly still and the pupil quite motionless. No more chloroform was given and the condition described last-
ed till the operation was over and the wound dressed. The patient was then aroused, and the pupil was observed to dilate simultaneously with his first manifestation of feeling.

The points noted in this case were

were, — (a) Dilatation of the pupil during the initial stage; (b) contraction which gave way to dilatation when the patient was irritated; (c) contraction with immobility co-incident with perfect anaesthesia; (d) a condition similar to that under (b); and (e) dilatation as sensibility returned.

2. M. M^d. act. 17; Scraping out necrosis of lens. The pupil dilated on commencing administration, but in about three minutes began to contract and gradually became smaller, the patient at the same time becoming perfectly quiet and motionless. Operation was proceeded with and did not cause any movement of the iris.

iris. The chloroform being withdrawn, after a few minutes slight dilatation of the pupil was noticed, immediately followed by struggling of the patient and other signs of returning consciousness. Administration was recontinued until the pupil was again fully contracted. It remained so till the conclusion of the operation but dilated quickly and completely on the patient being aroused.

3. J. S., aet. 40; Spinal section.
Pupil small at commencement. After a little chloroform had been given it dilated slightly and remained so for a minute or two during which time the patient struggled and shewed signs of excitement.

excitement. As he became quiet the pupil contracted to pin-head size. This condition lasted for several minutes and no more chloroform was given: the pupil then dilated slightly, the patient at the same time beginning to moan. Chloroform was then renewed and the pupil soon again contracted remaining so till the patient was aroused after completion of the operation.

In these two cases also dilatation was succeeded by contraction, (which did not last long but was maintained by the re-administration of chloroform) and dilatation again on the re-
-turn

=turn of consciousness.

H. R. S., aet. 57; Abdominal
Section. Pupil dilated in
a few seconds and remained
so for four minutes. The
patient did not struggle, the
conjunctival reflex was abolished,
the limbs were flaccid, and an-
-esthesia seemed complete. The
operation was commenced and
had so far proceeded that the
peritoneum was exposed before
any contraction of the pupil
could be observed. On
contraction commencing the
chloroform was withdrawn.
The pupil became of pin-head
size and remained so for many
minutes. It then relaxed
and at the same time the pa-
-tient

-tient showed slight symptoms of feeling; a few drops more chloroform were therefore given. This caused the pupil at once to contract again. After another considerable period the pupil dilated more widely than before, and immediately afterwards the patient vomited. At this point administration of ether was commenced, and the pupil did not contract under its influence.

In this case perfect insensibility was produced with the pupil still dilated but it is to be remarked that the patient was in an exhausted condition owing to intestinal obstruction of several days standing, and this probably

probably modified the action of the chloroform upon the iris.

The dilatation of the pupil preceding the effort of vomiting is noteworthy, but the full interest of the case was spoiled by the substitution of ether in the middle of the operation.

5. J. W., aet. 12; Excision of Metatarsal bones. Slight

dilatation soon after starting, followed very rapidly by contraction.

At the first insertion of the knife the pupil dilated widely, and a considerable quantity of chloroform was given before it began to contract again.

It remained contracted till near the end of the operation when slight

slight dilatation took place, immediately after which the patient became sick and vomited. This had the effect of almost completely arousing him from his state of anaesthesia and stupor.

The effect of sickness upon the pupil is here the most interesting point, - its general behaviour under the anaesthetic being as in the first three observations.

6. J. S., Oct. 14; Amputation of thigh. Several hours previous to the operation, eserine had been dropped into the right eye, consequently its pupil was contracted, while the left was considerably wider. Dilatation

=latation was observable in both after the first few in-
=halations of chloroform, though the movement of the right iris was limited on account of the action of the eserine. The left pupil remained dilated for about four minutes, and was variable when the patient was irritated by pinching, etc., then it began to contract. The boy seemed now deeply under the influence of the agent, the pulse was very weak, and the respiration slow and shallow. Commencement of the operation had not the least effect on the pupils both of which were strongly contracted, - the right one (eserine) to a pin-head size. The narcosis

narco-sis was perfect during the whole operation which lasted about ten minutes, and the pupils remained strongly contracted and immobile. As the dressings were being applied the left pupil dilated, and half a minute later the patient became sick and vomited. This had the effect of completely dilating the pupils, (the right one not very much, owing to the eserine), and seemed to awaken the boy, as immediately afterwards he began to cry out and exhibit other signs of suffering.

The action of eserine, it will be noted, is merely to increase the contraction and limit

limit the dilatation of the pupil. The effect of sickness in dilating the pupil and causing the immediate return of consciousness is also seen in this case.

7. M. G., aet. 26; Resection of bones of leg for ununited fracture.

Atropine had been applied to the right eye so that its pupil was widely dilated. The left pupil was in a contracted state. Immediately after commencing administration the left pupil dilated; no change was observable in the right. The patient's lips were cyanotic, and his respiration unsatisfactory from the beginning; the chloroform had therefore to be given with extra caution. In about five minutes the pupil became

became contracted, but the patient was not yet thoroughly narcotised because on the insertion of the knife the pupil at once dilated and he struggled faintly. A little more chloroform caused contraction to return, but it did not last long and soon gave way to dilatation. A few drops more chloroform were given till the pupil began to contract and so on throughout the operation which lasted over half an hour, the chloroform mask being applied when the pupil dilated and withdrawn when it contracted. In this manner the patient though never deeply under the influence of the drug was kept sufficiently still for the purposes.

purposes of the operation. The pupil dilated completely on his return to consciousness and a few minutes later returned to the contracted state it showed before the commencement of administration. No change could be noticed in the right pupil its action being evidently thoroughly paralysed by atropine.

8. M. H., aet. 7; Hip joint abscess. Right pupil previously dilated by atropine. Left pupil, which was of medium size before commencing, dilated with the first few inhalations of chloroform, the child crying and struggling violently. In three minutes contraction

contraction set in and the operation was proceeded with. The pupil remained contracted and motionless for about one minute, then began to dilate and in a few seconds the child groaned and struggled. A little more chloroform caused the pupil again to contract and rendered the patient insensible to pain. The same phenomena were repeated several times, viz:— contraction co-incident with perfect narcosis, and dilatation as recovery took place. After the operation, as the child awoke the pupil dilated to its fullest. No change took place in the eye which had been treated with atropine

M. Brown

From these two observations it will be seen that no modification is brought about by chloroform in a pupil paralysed by atropine.

9. N. M. B., aet. 74; Amputa-
-tion of thigh. Pupil dilated in half a minute after commencement but not to any extent, the patient taking the anæsthetic very quietly. In four minutes the pupil began to contract. In five minutes it was fully contracted, but manipulation of the limb caused dilatation. Some more chloroform was given and the pupil became immobile; the operation was then begun. The pupil kept in the contracted condition.

=dition for three minutes, the patient breathing quietly and shewing no sign of feeling. It then dilated gradually and the patient immediately afterwards began to struggle. More chloroform being administered the pupil again contracted and remained so for a few minutes then behaved as before. When the flaps were being stitched the pupil dilated widely and in a few seconds the patient vomited. This had the effect of bringing him back to consciousness and he asked if the operation was over. No more chloroform was given as very little remained to be done.

The dilatation of the pupil preceding

preceding vomiting and the effect of the latter in bringing about the return to sensibility are the chief features of this case.

10. S. G., aet. 6 mos.; Cauterisation of nares. Pupil dilated with the first few inhalations and was just beginning to contract when the cautery was applied. This produced dilatation again and slight struggles but the anaesthesia being quite sufficient for the purposes of the operation, no more chloroform was given. The pupil remained of large size.

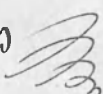
This case is interesting as serving to shew that extreme contraction

contraction of the pupil is not caused by chloroform unless the drug is pushed till complete anaesthesia is produced.

11. W. S., aet. 12; Removal of enchondromata. Pupils narrow. In about thirty seconds the pupil dilated, - not widely but quite distinctly. The boy took the anaesthetic very quietly without the slightest struggle. In three minutes the pupil contracted. The conjunctiva had been for more than a minute perfectly insensitive but the patient was not yet thoroughly narcotised, for on manipulating the hand he groaned, and the pupil dilated. When the pupil had been contracted for

for about a minute but still responded to excitations it suddenly dilated and in a few seconds the boy vomited. This brought him completely from under the influence of the chloroform and he became quite conscious. When the sickness had passed off, the administration was recommenced and in two minutes the pupil was strongly contracted. The operation was now commenced, the pupil remaining perfectly still and fixed in its contracted condition. A minute later it dilated but a few drops of chloroform caused it to contract again. This state was kept up throughout the operation.

operation, chloroform only being given when the pupil relaxed and taken away when it contracted again. On one occasion no chloroform was given when the pupil began to dilate, with the result that the patient in a few seconds moaned, struggled and interrupted the operation till he was made unconscious again. The administration was then conducted as previously. While the wound was being stitched the pupil, which had already slightly relaxed, dilated widely, and immediately afterwards the patient vomited. This awakened him and no more chloroform was given.

This 

This case demonstrates the practical advantage of the observation of the pupil with a view to keeping the patient in the state most suitable for the operation without narcotising him dangerously. When the pupil was strongly contracted, by noticing its first indication of dilatation and immediately administering some chloroform, the patient was kept perfectly motionless; but when this was omitted he became sensitive and interrupted the progress of the operation.

17. J. G., act. 16; Ovariectomy.
Pupils small before commencing. They dilated widely in one minute the girl crying and struggling.

struggling. In three and a half minutes the pupil began to contract, the patient at the same time becoming perfectly quiet. The conjunctival reflex was abolished, but the pupil dilated on any excitation by pinching, etc.. Five minutes from commencement of administration the pupil dilated widely and in a few seconds the patient vomited. This aroused her and she spoke as if conscious. Chloroform being continued the pupil in about one minute contracted, and in one minute more was of pin-head size, and did not respond to irritation. The operation was commenced without causing

causing any change in the size of the pupil. The pupil was kept in this state of atresia for fifteen minutes by giving a few drops of chloroform whenever the iris showed signs of relaxing. The pulse being at this time rather weak no chloroform was given though the pupil was beginning to dilate. In thirty seconds from the first sign of dilatation the pupil dilated quickly to its fullest, and the patient immediately vomited. The operation was interrupted, and the girl became semi-conscious and muttered incoherently. Chloroform was resumed, the pupil again contracted, and the patient became

became perfectly quiet. This condition was maintained for twenty minutes when the operation being nearly finished the chloroform was removed. The pupil soon began to dilate, and just as previously, in a few seconds dilated widely, the patient vomiting once more. This awakened her so completely that more of the anæsthetic had to be given for the wound to be stitched. She went under its influence and the pupil contracted as before.

The same phenomena were further noticed on the chloroform being withdrawn when the operation was finished, vizt., - wide dilatation of the pupil immediately

ly followed by vomiting and awakening of the patient.

In this operation the patient was only thoroughly motionless when the pupil was contracted and immobile.

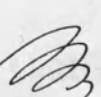
Whenever the pupil was allowed to dilate slightly it rapidly did so to its full extent and sickness followed in a few seconds.

This had its usual effect of arousing the patient.

The conjunctival reflex was abolished from a few minutes after the commencement of administration until the end with the exception of a few seconds after each occurrence of sickness.

B. Experiments.

As it was difficult if not impossible on account of the existing state of the law, to carry out a series of such experiments in this country, I performed them at Vienna in the university laboratory for experimental pathology, under the supervision of Professor von Basch. I proceeded in the following manner:-

In order to avoid the influence of the nasal reflex and for greater control over the amount of chloroform to be given, tracheotomy was in all cases performed and* the drug administered .

administered through a tracheal tube. An apparatus was constructed by which the chloroform vapour could be shut off instantly and fresh air admitted, with an arrangement for regulating the admixture of chloroform and air. The blood pressure in the carotid was traced on Ludwig's kymographion, the time recorded in seconds and the exact moment of change in the size of the pupil marked by means of Marey's electromagnetic signalling apparatus.¹ In nearly every case three separate administrations of chloroform

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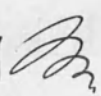
See Dr. M'Kendrick's Outlines of Physiology, Pages 91 and 355.


chloroform were given, with intervals for recovery intervening, and at the third the anæsthetic was pushed till death resulted. Tracings were taken in connection with every experiment performed, but as they all shew similar results, only one is annexed as a type of the others.

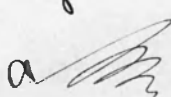
It will be noticed that a few experiments were tried, on the suggestion of Professor von Basch, which, though beyond the province of this paper, deserve to be mentioned, vizt., - the injection of strychnine with a view to resuscitation.

This alkaloid while failing several times either through too large

large or too small a dose being given, was successful in re-animating two dogs. — See experiments 3 and 5.

1. Young terrier of middle size. Wide pupils. 10-50 am. Administration of chloroform commenced. Full dilatation of pupil took place in forty-five seconds accompanied with struggling of dog. Half a minute later contraction followed, the animal becoming perfectly quiet and insensible. A knife stuck into various parts of the body caused no alteration in the pupil, nor did variations in intensity of light. After another half minute the blood pressure being very 

very low, (see chart), natural re-
-spiration was re-established. The
blood pressure in a few seconds
began to rise, and in about a
minute and a half pupil dilated.
A knife was then stuck into
the dog's leg which caused im-
-mediate complete dilatation of the
pupil and struggling of the animal.
An interval of ten minutes was
now allowed for the dog to recover.
At 11-6 a.m. the pupil resting in
a medium state chloroform was
recommenced. Immediate
violent struggling of the dog and
dilatation of the pupil took
place. A complete state
of dilatation was not reached,
but in half a minute contraction
began and soon the pupil was
reduced 

reduced to a very small size. The blood pressure had come down more rapidly this time and was now very low, (see chart), so normal respiration was re-established. The revival of blood pressure took longer than at the first administration, but when it had risen somewhat, (see chart), gradual dilatation of the pupil was observed and the dog again became sensible. Another interval of ten minutes was given. At 11-24 a.m. chloroform was recommenced. The pupil widely dilated in fifteen seconds accompanied by struggling of animal. It did not begin to contract for more than a 

a minute and reached com-
-pletion slowly. Chloroform
was still pushed, and two
minutes later the pupil dilated,
immediately after which respira-
-tion ceased and the blood
pressure was reduced to nil,
(See chart). Without
having recourse to artificial
respiration about $\frac{1}{50}$ grain of
strychnine was injected into the
jugular vein which caused pulse
and respiration to return within
a minute. These were both
gradually increasing in strength
when they suddenly began to
get weaker and quickly ceased
altogether, (See *chart). It
was not till then noticed that
the chloroform apparatus had
not ~~been~~

not been withdrawn when respiration ceased and free access of air was therefore prevented, so that the dog had really been poisoned a second time. Another dose of strychnine was injected but it was too late as it had not the slightest effect.

This experiment demonstrates the relation between the state of the blood pressure and the modifications in the pupil, contraction each time occurring when the pressure had fallen a certain length and dilatation when it had risen again. It also illustrates the rapid poisoning which ensues when the chloroform is pushed after the ~~B₃~~^{B₃}

the pupil has become strongly contracted.

2. Small young terrier. Wide pupils. 9-55 a.m. Chloroform administration commenced: immediate dilatation of pupil accompanied by violent struggling of the animal. The pupil remained completely dilated for a few minutes then contracted slightly, and in half a minute more dilated again. The dog was still struggling. A leak was at this moment discovered in the tracheal tube on account of which the dog was inhaling scarcely any chloroform. After re-adjustment of the apparatus chloroform was again given at 10-2

10-7 a.m. Complete dilata-
-tion followed in half a minute
with wild struggles. The
dilatation remained for two
minutes, the struggles of the
animal gradually subsiding,
then contraction commenced
and reached completion in
half a minute. The dog
by this time was perfectly still,
and the insertion of needles
caused no reflex action. As
in the previous experiments the
contraction of the pupil was
co-incident with a considerable
fall in the blood pressure, and
therefore half a minute later
natural breathing was re-establi-
-ed. After the dog had
been allowed a few inhalations
of $\frac{2}{3}$

of fresh air the pupil quickly dilated, and the struggling of the animal recommenced. Ten minutes interval of natural breathing was now allowed, during which time the pupil varied according to the dog's struggles, irritation by light, etc., when undisturbed it rested in a medium state. At 10-19 am., the administration of the anaesthetic was recommenced. Rapid and complete dilatation accompanied by struggling, followed in a minute and a half by contraction with perfect quietude, the latter coincident as before with fall in blood pressure. One minute later the chloroform was again

=gain withdrawn. In a
minute and a half pupil
began to dilate with at the
same time returning signs of
consciousness. During the
period of strong contraction
the animal was irritated by
needles and knives, but the
pupil remained immobile.
After dilatation had begun the
same irritations caused sudden
increase with signs of feeling.
Another ten minutes interval
for natural breathing having
been given, chloroform was
commenced at 10-35 a.m., for
the third time. The
result was immediate dilata-
-tion not complete and at
once followed by contraction.
This

This time there was very little struggling of the animal. The chloroform was still continued and in one minute the pupil dilated suddenly and remained fixed and immobile in its dilated condition. A little later respiration, which had become gradually slower, altogether ceased. Injection of strychnine had no effect.

The same phenomena were observed in this experiment as in the last. One point of special interest is noted at the commencement, viz. - the absence of contraction of the pupil when chloroform was not administered in sufficient dose, and its prompt contrac-

-tion.

-tion when that error was rectified. The relation of general sensibility to the state of the pupil is also shown. When dilatation occurred in response to peripheral irritation the general anesthesia was found to be insufficient, but when the pupil became perfectly motionless and irritation brought about no change, the narcosis was found to be complete.

3. Young dog. Small pupils. 9-59 am. Administration commenced.

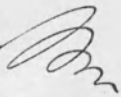
Sudden and rapid dilatation of pupil complete in twenty-five seconds. In one minute it began to contract and this condition also reached its

its full extent very quickly.
The dilatation was accompanied
by the usual excitement and
struggling of the dog; as the
contraction took place these
gradually subsided and soon
altogether ceased. After
pursuing the administration for
one minute with the pupil
strongly contracted, it was
stopped and fresh air sup-
plied. Thirty seconds
later the iris began to relax
and shortly afterwards strong
dilatation took place. Ten
minutes natural breathing were
now allowed and the pupil
regained its original condition,
viz., - a state of moderate con-
traction.

At 10-16 am.

Chloroform

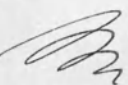
Chloroform was again given. Immediate and rapid dilatation, followed as before in about half a minute by contraction. Struggling occurred during dilatation, and perfect stillness as the pupil became contracted. The blood pressure having fallen very low and respiration being unsatisfactory chloroform was almost immediately withdrawn and fresh air admitted. As in every other previous instance the blood pressure began at once to rise. The pupil remained strongly contracted for two minutes when excitation by needle pricking caused dilatation and signs of feeling. Other ten minutes

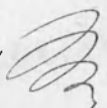
=utes interval having elapsed, at
10-30 a.m. administration was
re-commenced. Again
immediate dilatation was ob-
=served, accompanied by strong
=gling of the dog. This
time the dilatation took about
forty-five seconds to reach its
utmost and it began to
contract thirty seconds later,
reaching its narrowest limit
in thirty seconds more. The
chloroform was continued with
the pupil in its state of
strong contraction for one
minute and a half when
respiration suddenly stopped
and the pupil dilated ex-
-actly at the same moment,
the blood pressure became
much 

much lower, and the pulse very slow. Chloroform was removed and artificial respiration practised for a minute and a half without any effect; $\frac{1}{50}$ grain of strychnine was then injected into the jugular vein. In a few seconds the dog gave a convulsive gasp then began slowly to breathe. As this occurred the pupil again became contracted and remained so for a few minutes. It then dilated and at the same time the dog showed signs of feeling. The blood pressure, which had gradually risen, was now as high as before commencing the

the experiment. In about five minutes tetanic spasms suddenly set in the pupil dilating very widely. These continued for a minute or two and the dog seemed to be dead, but he gradually came round again, and in the space of five minutes was respiring quietly.

The remarkable effect of strychnine as a means of resuscitation is the chief new feature of this experiment.

4. Small lap-dog, thin and delicate. Vessels very much thickened by stromous deposit. 10-15 am. Chloroform commenced. Im=mediate 

=mediate dilatation of pupil
accompanied by wild strug-
-gling of dog. In about
a minute the animal became
perfectly quiet and unconscious,
no response being made to
irritations but the pupil was
still widely dilated. In
about two and a half min-
-utes from first inhalation
the pupil began to contract
and advanced rapidly to
a very minute size. As
the blood pressure was now
very low and breathing slow
and laboured the chloroform
was taken away and fresh
air supplied. This did
not cause the usual revival
of the blood pressure, and
in 

in about half a minute the pupil dilated while at the same time respiration stopped and the pulse failed. Artificial respiration was tried and strychnia injected into the jugular vein. The pulse returned faintly but was not accompanied by respiratory effort and soon ceased again.

The time which elapsed before the pupil was completely contracted was longer than usual, and the dog had therefore a larger dose of chloroform. This fact taken with the apparently weakly condition of the animal probably accounts

-counts for its death. This case illustrates the danger of pursuing the administration of chloroform even for a few seconds after the pupil has become strongly contracted and motionless.

5. Small young terrier.

Pupils medium size. 10.41 a.m. Chloroform commenced. In twenty-five seconds dilatation of pupil which increased till it was complete. In thirty-five seconds more the pupil began to narrow and continued to do so till it was in a strong state of contraction. The dilatation was accompanied by struggling of the animal and the contraction

-traction with gradual loss of consciousness. The latter was co-incident with fall in the blood pressure as in all the previous experiments. The pupil being now strongly contracted chloroform was withheld and fresh air admitted. In one minute the pupil began to dilate. In another minute it was fully dilated and the dog struggled again as before. During a ten minutes interval the pupil returned to much the same state as it was in before starting the experiment. At 10-58 administration was recommenced. In about

a

a minute the pupil began to dilate but did not do so to any extent as contraction set in almost at once. In two minutes from the time of starting, pupil was completely contracted and the blood pressure again being low fresh air was substituted for chloroform. The pupil did not dilate for six minutes and even then notwithstanding vigorous irritations with needle and knife no sign of feeling was manifested till another minute had elapsed. Ten minutes interval of natural breathing was again allowed and

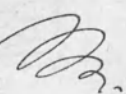
and at 11-20 am. Chloroform was recommenced. Within thirty seconds dilatation of the pupil began and within one minute was complete. It remained so for two and a half minutes the blood pressure gradually subsiding; then the pupil began to diminish and was fully contracted in another minute. After a few moments the chloroform was taken off. The pupil remained strongly contracted for six minutes and then dilated in response to irritation. Another interval of ten minutes having elapsed, at 11-41 a.m. chloroform was again given. Within

respiration was employed for about a minute when spontaneous respiration took place. This gradually increased for about five* minutes when it became spasmodic; in other five minutes the tetanic state began to pass off and breathing again became natural. After this the animal progressively recovered, the tracheotomy and carotid ligature wounds were stitched and the animal left breathing vigorously with occasional slight tetanic symptoms.

The tardy action of the chloroform as compared with the former experiments is here to be noted, and the action of

in about a minute began to contract. When it had become very small and motionless the anesthetic was removed and fresh air admitted. Pupil remained strongly contracted for five minutes when it dilated and the dog showed signs of sickness. This aroused him and struggling began. After another interval of ten minutes, at 10-20 a.m. administration was recommenced. Immediate dilatation of pupil, followed very shortly by contraction which rapidly became complete. After a few seconds, the blood pressure being extremely low, the

the chloroform was removed. The blood pressure at once began to rise, but the pupil did not relax for fifteen minutes. The dog, which throughout the stage of contraction remained perfectly quiet and insensitive to any kind of excitation, now commenced to struggle, and responded to irritation. After ten minutes interval chloroform was renewed. The initial dilatation was again followed quickly by contraction. Administration was still continued and in one minute the pupil dilated suddenly and at the same moment the dog ceased to breathe.

The 

The modifications in the pupil are here the same as in the previous experiments, viz., - dilatation with excitement; contraction with perfect anaesthesia, and dilatation with recovery, or with asphyxia caused by an overdose.

These clinical observations and experiments, which are selected from a series of over fifty, represent what happened in the large majority of cases. In a few the phenomena were somewhat variable, but could always

human subject when chloro-
-form vapour is introduced
directly to the lungs through
a tracheal tube.

From my investigations
I have no hesitation in say-
-ing that the conclusions of
Budin and Bojme above quoted
are for the most part correct,
excepting the one (VII) from
which they advise that the
pupil be kept in a state
of atresia with immobility for
a long period. That
this direction is not only
impracticable but dangerous is
proved by all my experiments.
Nor in every case where the
chloroform was pushed for very
little

little over a minute after the pupil had become strongly contracted, sudden dilatation occurred and the animal almost at the same moment ceased to breathe. From this state of apparent insensibility it was possible to resuscitate the dog by the usual means but it is very doubtful if this could be accomplished were the drug administered in the ordinary way; because in the experiments artificial respiration could be promptly and effectively applied through the tracheal tube, - an arrangement not usually applicable in operations. And even with

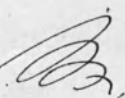
with all this advantage, in one or two instances the attempts to revive the animals entirely failed.

With regard to the practical value of observing the pupil when giving chloroform, it must be admitted that this is considerably reduced by the fact that there is no change, (so far as I have seen), which gives warning of the imminence of accidents in time to admit of their prevention. The dilatation which is seen when the drug is pushed after the pupil has become strongly contracted is the dilatation of asphyxia and occurs, I am afraid, too late

late for any hope of resuscitation. I have never pursued the administration far enough in the human subject for this dilatation to be produced, because in all cases when the pupil became contracted and immobile the narcosis was profound; and I considered it risky to continue the chloroform. The danger in so doing is proved by what happened in the experiments described when the chloroform was continued after the pupil had become strongly contracted. But the observation, which notwithstanding many statements to the

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the contrary I think is un-
questionably reliable, that
modifications occur in the
pulse bearing a constant
relation to the state of sen-
sibility, surely proves that
it is well worth observing,
especially when this can be
done without at all prevent-
ing proper attention to other
symptoms of importance.

The watching of the respira-
tion and the pulse which
are doubtless the best indica-
tions of the effect produced
on the individual and there-
fore of vital importance for
safe administration does not
in many cases furnish evi-
dence of the state of sensi-
bility. 


=bility, in regard to which I hold the observation of the pupil to ^{be} of greatest assistance. The sign usually relied on, viz: - the insensibility of the conjunctiva is by no means a satisfactory test, for in many cases conjunctival anaesthesia is established long before the patient can be said to be under the influence of the drug. By observing the pupil a person giving chloroform can tell at once when the effect of the drug on the sensibility is on the wane, because the pupil then begins to dilate and react to excitation by the knife etc. - Noticing this

this he can by the adminis-
-tration of a few drops more
chloroform till the pupil con-
-tracts again, prevent the oc-
-currence of struggling and
interruption of the operation.
In this way he can keep
the patient in the state most
suitable for the satisfactory
performance of the operation
without narcotising him more
than is necessary. The
amount of chloroform required
to maintain a state of an-
-esthesia is much less than
that required to put a
patient under its influence
several times, and as it is
admittedly a dangerous drug
the less administered the better,
especially

especially in operations of long duration. And by allowing the patient partially to recover one runs the risk of the occurrence of sickness and vomiting which is always an awkward and often a dangerous accident. In the absence of such a guide as the observation of the pupil, the chloroform must be given in a rather hap-hazard way, dosing the patient till narcosis is profound, perhaps too much so, then interrupting the operation till the danger is averted by arousing him or waiting until signs of feeling, such as struggles or a cry of pain, give indication for more chloroform.

=form.

The observation of the pupil also furnishes a fair indication of the effect produced by chloroform. On consulting the chart annexed, the relation of the size of the pupil to the state of blood pressure will be at once noticed. Contraction of the pupil only occurred when the blood pressure had fallen considerably, and on removal of the chloroform dilatation only took place when the pressure had risen a certain height. As reduction of the blood pressure was pronounced by the

Scientific 

Scientific Grants Committee of the British Medical Association¹ to be one of the chief dangers in chloroform administration, the presence of a sign by which the occurrence of that important condition can be recognised must be of practical value.

In conclusion I have to state as the result of my investigations the following opinions: -

1. The effect produced by chloroform on the pupil is at first dilatation varying in degree and duration, then contraction as the narcosis

¹ British Medical Journal; December 18th, 1880.

-cosis becomes profound, and dilatation again when the sensibility is returning. If the administration be still continued with the pupil strongly contracted and motionless, the pupil will also dilate, but in this case more suddenly and completely, and will be coincident with a state from which it will be difficult or impossible to resuscitate the patient.

This latter is the dilatation of asphyxia.

2. So long as the pupil dilates in response to excitation by pinching, etc., the patient is not sufficiently narcotised for the operation

to

to be proceeded with, - unless the latter is slight and does not require complete anaesthesia.

3. When the pupil becomes strongly contracted and immobile no more chloroform should be given until it begins to dilate again. If then further anaesthesia be required a little more chloroform should be given till the pupil again contracts.

4. The occurrence of sickness causes dilatation similar to but more sudden than that which happens when sensibility is returning, and the efforts of vomiting have the effect of arousing the patient.

JK

It is not the purpose of this paper to undervalue in the smallest degree the indications afforded by the respiration and circulation in the administration of anesthetics, but rather to supplement these by a sign which can easily be observed in conjunction with them. The observation of the lips, which is the most convenient method of watching both respiration and circulation, can be attended to at the same time as the state of the pupil. While I consider therefore that attention to the former is of first importance, I at the same

same time believe the latter
to be of valuable assistance
and worthy of observation
by every one who adminis=
ters chloroform.