sumed eating, and presented no other symptoms. If I had been a little less cautious in the avoidance of fallacy, it is very likely I should, in observing these muscular phenomena in two of the experiments, have succeeded in seeing attempts to vomit; but they assuredly were not such, for they did not in any degree resemble the efforts made by the same animals to evacuate the bladder and rectum, or the efforts made by the dog and man to empty the stomach through the œsophagus.

Considering the vague manner in which M. Dupuy alludes to his experiments, and, on the other hand, confident of the fairness with which my own have been conducted and recounted, I feel myself justified in opposing my conclusions to his, and in stating that all the attempts hitherto made to excite efforts to vomit in the horse by emetics have failed. This unsusceptibility to emetic action, and the very rare manifestation of the phenomena of vomiting by the horse, must obviously be regarded as cause and effect, and, consequently, as the answer to the question, Why does the horse rarely vomit?

7th February, 1852.

ON THE CAUSE AND PREVENTION OF DEATH FROM CHLOROFORM.

By JOHN SNOW, M.D.

(Concluded from p. 423 of May number.)

I HAVE examined the viscera of the chest, and kept notes of the appearances, in thirty-seven animals killed by chloroform. They consisted of two dogs, twenty-two cats, one kitten, three rabbits, three guinea-pigs, two mice, two larks, and two chaffinches. Many of the animals were opened immediately after death, and the rest within a day or two. The lungs were not much congested in any instance. In seven of the animals they were slightly congested; but, in the remaining thirty, the lungs were not congested. They were generally of a red colour, but in a few of the cats they were quite pale. I ascertained the specific gravity of the lungs of two of the cats, in which they presented the amount of vascularity I have most usually met with. They were weighed first in air, and then in distilled water, and the specific gravity was found to be 0.605 in one instance, and 0.798 in the other. As many of the animals died in a way resembling asphyxia, the respiration ceasing before the circulation, it might at first be supposed that we should meet with the same congestion of the lungs; but, by the time that the respiration is altogether suspended by the action of chloroform, that agent has begun already to influence the heart, which does not inject the blood into the lungs with the same force as when the respiration is mechanically prevented, whilst it is in full vigour. Besides, in the gaspings which so often take place when the heart is ceasing to act, the animal inhaling chloroform draws air freely into the lungs, whilst the asphyxiated animal is prevented from doing so. Mr. Nunneley and Mr. Thomas Wakley met with congestion of the lungs in many of the animals which they killed with chloroform. I am unable to explain how this happened; but Mr. Richardson, who

spoke lately at the Medical Society of London, when I read a paper on the subject of which I am now treating, said, "when animals had been killed by it, he had found that the red colour of the lungs was inviolable, but those organs were not congested, neither was the brain."¹

As regards the condition of the heart, it was found in the two chaffinches that the right and left auricle were filled with blood, whilst the ventricles were empty. The condition of the heart in the larks is not mentioned, but in all the thirty-three quadrupeds the right auricle and ventricle were filled with blood. In ten of them, these cavities were much distended; and, in some of these instances, the coronary veins on the surface of the heart were distended also. The left cavities of the heart never contained more than a small quantity of blood, not exceeding about a quarter of what they would hold.

The head was examined in only ten of the animals. The substance of the brain was found to be of the natural vascularity, and the sinuses were not very much distended, except in two instances.

With respect to the state of the blood, it may be mentioned, that in every instance in which the chest was opened within an hour after death, the blood which flowed from the cut vessels coagulated immediately and firmly. In eighteen of the animals in which the blood was examined in the heart or large vessels, a day or two after death, it was found to be coagulated in ten, loosely coagulated in seven instances, and quite fluid in one instance.

I have not met with air in the blood-vessels, either in the thirty-seven *post-mortem* examinations of which I retain notes, or in any of the numerous other animals that I have opened after they have been killed by chloroform; nor have I met with it in animals killed with ether and various other volatile narcotic substances.

The appearances met with in the cases of accident in the human subject differ somewhat from those described above. In some of the cases, however, the *post-mortem* appearances have been modified by the artificial respiration and other measures employed with a view to restore the patient. The following is a brief summary of the inspection in the fatal cases in which an examination took place after death.

CASE I. Hannah Greener. *Lungs* congested; epiglottis reddened, as also mucous membrane of larynx. *Heart* healthy; dark fluid blood in both its cavities; very little in the left. *Brain*, externally and internally more congested than usual. Liver, kidneys, and spleen, congested.²

CASE II. Mrs. Simmons. *Lungs* congested, crepitant, no extravasation; congestion of lining membrane of bronchi; great injection of pleura; six ounces of bloody serum in right, two ounces in left. *Heart* flaccid; cavities empty; inner surface of all the cavities deeply stained; six drachms of bloody serum in pericardium. *Brain*. General aspect, colour, and consistence, normal. A larger quantity of blood than usual flowed from the vessels of the dura mater. Superficial vessels of the brain moderately distended. Two or three ounces of fluid blood, intermixed with bubbles of air, flowed from the sinuses of the dura mater. *Blood*, quite fluid in every part of the body.³

¹ Med. Times and Gaz., vol. i, p. 253.

² Lancet, 1848, vol. i, p. 161.

³ Med. Gaz., vol. xlii, p. 81.

The cavities of the heart had evidently been emptied after death by the artificial respiration which was employed; and if the bubbles of air met with in the sinuses of the dura mater did not enter during the dissection, they were probably introduced into the circulation by the rupture of the air-cells, whilst inflating the lungs.

CASE III. Patrick Coyle. *Lungs* studded with tubercles; abscess in each; lower part congested; pleura adherent. *Heart* enlarged, pale, and soft; two or three ounces of serum in pericardium; blood-vessels with dark fluid blood. *Brain*, with its membranes, natural and healthy.¹

CASE IV. No inspection.

CASE V. Madlle. Stock. *Lungs* visibly engorged in the lower lobes, "pulmonary vesicles dilated by the air blown in during the last moments of life, with a view to reanimate the patient." *Heart* flaccid, of the usual size; cavities absolutely empty. *Brain* firm; no drops of blood escaped on cutting into it. *Blood* very black. Air was met with in the pulmonary veins, in the carotid arteries, in the veins and sinuses of the head, and in the veins generally throughout the body.²

In this case also the cavities of the heart had been emptied after death by the artificial respiration. The air-cells were permanently distended by the same cause, and some of them must have been ruptured to allow the air to enter the pulmonary veins, from whence, being passed through the left cavities of the heart, it was forced by the contractility of the arteries into the veins of various parts of the body. Many of the French physicians who have written, or spoken, on this case, seem to have overlooked the circumstance that the arteries have the power of expelling their contents through the capillaries into the veins, after the heart has ceased to act.

CASES VI AND VII. I have met with no account of any examination.

CASE VIII. John Griffith. *Lungs* a good deal congested, and discharged, when cut, a large quantity of bloody serum. *Heart* large; its ventricles and auricles empty; its condition flabby; the substance of the left ventricle rather softer than natural. *Brain* healthy; no other appearances than in persons dying when in full health.³ It is not stated whether artificial respiration was performed in this case, but it most likely was.

CASE IX. J. Verrier. *Lungs* of a very black colour, otherwise their tissue was healthy. *Heart* flaccid and empty, [artificial respiration had been performed.] *Brain* normal; sinuses of dura mater contained a considerable quantity of black uncoagulated blood. *Blood*, fluid, except a fibrinous clot on the Eustachian valve of the heart.⁴

CASE X. Samuel Bennett. *Lungs* of a dark venous hue throughout, a large quantity of blood escaping from them when cut into. Mucous membrane of trachea and bronchi congested. *Heart* rather large but flabby; auricles empty; each ventricle contained about an ounce of semi fluid blood; (the lungs had been inflated.) *Head*. Sinuses and veins contained blood, but not to any remarkable amount. But few bloody points occurred in cutting into the cerebral mass. *Kidneys* congested.⁵

¹ Med. Gaz., vol. xliii, p. 683.

² Ibid., vol. xlii, p. 212.

³ Ibid., vol. xliii, p. 684.

⁴ Ibid., p. 745.

⁵ Lancet, 1849, vol. i, p. 206.

CASE XI. Madame Labrune. No inspection reported.

CASES XII and XIII. No inspection.

CASE XIV. Young lady, Berlin. *Lungs* presented nothing morbid; the bronchi contained a little bloody froth. *Heart* was soft, flabby, and collapsed. Decomposition had commenced in it. Its cavities were empty. The blood was of the colour and consistence of cherry juice. *Head*. The membranes of the brain were slightly congested. The sinuses were not unusually full of blood. The substance of the brain was in its natural condition.¹

CASE XV. Artilleryman. *Lungs* emphysematous. *Heart*. Its right cavities were filled with fluid blood. *Head*. The sinuses of the dura mater contained less blood than usual, and the brain was pale.

CASE XVI. Alex. Scott. *Lungs* extremely congested. *Heart* feeble and flabby, not particularly distended; about two ounces of fluid blood on the right side; not more than half an ounce on the left. *Head*. Much congestion of the dura mater; the grey matter of the brain was dark and congested; fluid was found in the subarachnoid space, and a considerable quantity of it in both ventricles. *Kidneys* congested.²

CASES XVII and XVIII. No inspection.

CASE XIX. Madame Simon. *Lungs* somewhat congested, and emphysematous. *Heart* flaccid, of middle size. Right cavities filled with liquid dark-coloured blood, mixed with some fibrinous clots. The left cavities contained similar blood, in much smaller quantity.³ Chloroform was detected in the blood, in the lungs, spleen, and various other organs, by a chemical process nearly the same as one which I employed about two years ago for the same purpose.⁴ It was detected in the blood even when it had become putrid. As chloroform cannot be perceived by its odour in the dead body, and as the *post-mortem* appearances it leaves are neither striking nor constant, its easy detection by chemical means is of considerable importance. Its presence does not prove, however, that death was caused by chloroform, but only that this agent was taken at or near the time of death; for it can be detected with great facility in portions of the body removed by surgical operation, when the patient is under its influence.

CASE XX. Thos. Hutton. *Lungs* much loaded with fluid blood, and containing a large quantity of serous infiltration. *Heart* flabby and soft; its cavities contained only a very small quantity of dark fluid blood. (The lungs had been inflated.) The muscular substance of the heart was examined with the microscope; "here and there a minute oil globule could be observed in the muscular fibrillæ, but nowhere did this amount to fatty degeneration." *Head*. Vessels of the dura mater, and on the surface of the brain, gorged with fluid blood. A considerable quantity of serous fluid in the cavity of the arachnoid, and a large quantity flowed also from the spinal sheath. The substance of the brain was very soft. (The weather was warm.) *Kidneys* congested.⁵

CASE XXI. No inspection.

CASE XXII. At St. Bartholomew's Hospital. *Lungs*. Their texture

¹ Med. Gaz., vol. xlv, p. 484.

² Lancet, 1850, vol. ii, p. 21.

³ L'Union Médicale, January 29, 1852.

⁴ Med. Gaz., vol. xlv, p. 321.

⁵ Med. Times, 1851, vol. ii, p. 98.

was healthy, but they appeared more than usually collapsed and dry. Their large blood-vessels were not over filled. The mucous membrane of the large bronchi and trachea was turgid. *Heart* healthy, natural in its texture. The right auricle and ventricle were distended with blood. The left auricle and ventricle contained very little blood. The blood was all fluid, and presented a brownish purple hue, like that which is usually met with in the spleen. *Head.* Some adhesions of the membranes of the brain, from disease at a previous period. Otherwise the appearances were healthy.¹

CASE XXIII. At Stockholm. No report of any examination.

It will be remarked, that congestion of the lungs was more frequently met with in the above cases, and to a greater extent, than in the animals which I killed with chloroform; and, also, that the blood was more frequently fluid. A fluid state of the blood is very frequent in sudden death, in the human subject, from any cause, as I have had many opportunities of verifying; and the reason why it is less often met with in the smaller animals is, probably, because their bodies cool more quickly after death.

As regards the prevention of death from chloroform, it must be evident, from what was previously stated, that the chief means to be employed for this purpose, is to have the vapour sufficiently diluted with air. The methods of ensuring this dilution were previously alluded to; but I should like to observe, in this place, that it would be well if all those who do not feel confident that they can employ chloroform without incurring any risk to the patient, were to confine themselves to the use of sulphuric ether, an agent which is incapable of causing death in the sudden manner in which it has taken place in all the accidents from chloroform previously detailed.

Many persons at one time supposed that the deaths from chloroform were caused by a want of care in selecting the cases for its employment—an opinion natural enough in those who had not had the time or opportunity to study all the physical conditions connected with the exhibition and action of the agent. The particulars of the fatal cases which have occurred show, however, that the unfortunate results did not depend on any peculiarity of the patients; and the truth is, that whilst chloroform, if not well managed, may cause the death of the most robust and healthy person, it may, on the other hand, with due care, be safely administered to the most feeble and diseased, as I have had numerous opportunities of observing. It is, undoubtedly, both proper and desirable to take into consideration every circumstance connected with the condition of the patient, before administering chloroform; but, wherever there is severe pain to be prevented or removed, it may, according to my experience, always be employed without ill consequences, if sufficient care be observed.

There is a very general impression, that the use of chloroform is unsafe where disease of the heart exists, although no good reason has been given for this impression. I may remark, in the first place, that no great amount of disease of the heart has been met with in any of the fatal cases of administration of chloroform, in which the body has

¹ Med. Times and Gaz., 1852, p. 319.

been examined; and, in the second place, that I have several times given this agent during surgical operations, when very marked disease of this organ existed, and to a great number of old people, in whom the arcus senilis in the cornea might lead to suspicion of its being affected with fatty degeneration. The fact of chloroform being able to arrest the action of the heart, might appear to indicate that it is prejudicial to that organ; this circumstance, however, does not arise from any peculiarity in the mode of action of this agent, but only from its physical properties being such that it is capable, under certain circumstances, of being absorbed in sufficient quantity to narcotise the heart. I find that sulphuric ether will produce the same effect, if the inhalation be continued by artificial respiration as soon as the natural breathing ceases; and that diluted alcohol will also arrest the heart's action, if it be injected into the coronary arteries immediately after death, whilst contractions are still taking place. The action of chloroform on the circulation, when sufficiently diluted with air, is that of a stimulant. It has a very marked effect in preventing syncope during surgical operations; and, as syncope is attended with danger in diseases of the heart, there is reason to believe that the careful administration of chloroform is a means of safety to patients who, notwithstanding the heart disease, have to undergo an operation. Moreover, the pain of even a slight operation has generally the effect of accelerating the pulse to about twice its natural frequency; and it is well known that mental excitement, muscular exertion, or any other cause which has such an influence on the circulation, may occasion sudden death where there is disease of the heart; but, as the pulse usually remains of its natural frequency and force during an operation under the effects of chloroform, this circumstance further confirms the conclusion that the careful use of this agent is a source of safety, and not of danger, to the patient with heart disease. In these patients, however, I think it desirable to conduct the inhalation in such a manner that excitement and struggling may be avoided, and not to prolong the use of chloroform longer than is absolutely necessary, for protracted insensibility is sometimes followed by depression. I am happy to be able to quote the opinion of Dr. Sibson, who has paid great attention to the subject of chloroform, in favour of its employment under certain circumstances where there is disease of the heart. He says, "persons the subjects of heart disease, when the dread of a severe operation is great, may sometimes be peculiarly benefited by the careful and short production of anæsthesia during the cutting part of an operation."¹

It remains now to treat of the measures to be adopted in case of an overdose of chloroform; and it may be remarked in the commencement that, in any case in which the respiration and circulation both continue after the lungs have been emptied of the chloroform which was contained in them at the moment when the inhalation was discontinued, the patient will most likely recover, however alarming his symptoms may appear; for at this moment he begins to get rid of the chloroform, by its being exhaled from the blood as it passes through the lungs.

¹ Med. Gaz., vol. xlii, p. 111.

From the good effects of dashing cold water on the surface, applying ammonia to the nostrils, and using means of a similar character, for exciting respiration in certain cases of narcotic poisoning, it might at first be supposed that like measures would be very useful in accidents from an overdose of chloroform. It must be borne in mind, however, that in the ordinary and safe administration of this agent, when it is desired that the patient should lie without flinching during a surgical operation, the sensibility is often temporarily diminished to the extent that no reflex motions are caused by the strongest stimuli that can be applied; and it is impossible that a further dose of chloroform should restore the sensibility. I have dashed cold water on animals, and applied ammonia to their nostrils, without the slightest effect, whilst the insensibility was kept within safe bounds; and, on one occasion, Mr. Marshall and I found that the strongest ammonia produced no effect on a guinea-pig, at a time when it was still sensible to having the nose and feet pinched with the forceps. In cases in which the action of the heart might be arrested by the influence of a few ounces of blood overcharged with chloroform, whilst the body at large was not insensible, these ordinary excitants of respiration might have some effect. There would, therefore, be no impropriety in trying such means, provided they were not allowed to occupy the time which ought to be employed in more important measures; and patients have recovered under their use, who appeared in danger; but it is most probable that these patients would have recovered spontaneously, if nothing had been done, for I have in numerous instances observed the unassisted recovery of animals that appeared dead from the effects of chloroform.

The most important measure in the treatment of a case of threatened death from chloroform is artificial respiration, which, I believe, would restore the patient in most instances, if it were put in force within half a minute after the natural breathing had ceased.

The following experiment, in which I was assisted by Mr. Marshall, shews the success of this measure on an animal, when promptly applied.

EXPERIMENT VII. A cat was made insensible by breathing chloroform in a large jar. An incision was then made in front of the neck, the trachea was opened, and a tube was introduced and secured. A bladder, filled with air containing four per cent. of vapour of chloroform, was attached to the trachea tube, by means of a stop-cock, with which it was armed. The stop-cock being opened, the cat breathed to and from the bladder. The capacity of the bladder was a hundred and twenty-five cubic inches, and five minims of chloroform had been introduced previously to filling it with the bellows. A fresh bladder, of the same size, charged with chloroform and air in the same manner, was substituted every three or four minutes for the former one. After a time, the breathing began to be feeble, and, twenty minutes after the inhalation from the bladder commenced, it ceased altogether. The action of the heart continued, however, to be very distinctly heard with the stethoscope for half a minute, when its pulsations were becoming slow. At this moment the stethoscope was removed, in order that I might assist in commencing the artificial respiration, which was performed by attaching a bladder filled with air to the tube in the trachea, and making gentle pressure on the bladder about thirty times a minute.

On listening to the chest again, just after the artificial respiration had been commenced, the heart was heard beating with extreme rapidity. After the artificial respiration had been performed for about a minute, the cat was observed to breathe of itself. The bladder was removed, and it was allowed to breathe through the tube. It began to show signs of sensibility almost immediately, and in ten minutes it had recovered nearly altogether from the effects of the chloroform. At this time the cat was made to inhale air containing ten per cent. of vapour of chloroform; twelve and a half minims having been put into one of the bladders previously used. Both the breathing and the heart were soon affected, the breathing being at times very quick, and at other times feeble, and the action of the heart being rapid, and occasionally almost inaudible. At the end of about three minutes the bladder was changed for another, containing the same quantity of chloroform and air; and, in three minutes more, or six minutes after the beginning of the inhalation, the cat ceased to breathe. The heart's action had become almost inaudible before the breathing ceased. It was, however, just perceptible afterwards, though very feeble and indistinct. Artificial respiration was set up as before, with a bladder full of air, within half a minute after the cat ceased to breathe. In a little time the action of the heart became more audible, and in a minute or two the cat breathed by its own efforts. In a very few minutes, and before the animal had recovered its consciousness and voluntary motion, the experiment of making it breathe air charged with ten per cent. of vapour was repeated in the same manner. Two bladders were used as before, and the breathing ceased again in six minutes. The sounds of the heart became very indistinct a little time before the breathing ceased, and, when the cat ceased to breathe, no sound of the heart could any longer be heard. Artificial respiration was commenced immediately, and, in about half a minute, feeble and rapid sounds of the heart could again be heard. In a minute or two the heart's action was very audible, but it was two or three minutes before the breathing recommenced by the muscular action. In two or three minutes more the cat was in a fair way to recover altogether from the effects of the chloroform, when it was made the subject of a different kind of experiment.

I believe that the breathing would have recommenced after the first inhalation, and that the cat would have recovered spontaneously, without the aid of the artificial respiration; but I consider that its restoration after the second, and more particularly after the third inhalation, was entirely due to the artificial respiration; for I have never seen an animal recover without assistance, when the breathing and action of the heart had been simultaneously arrested by chloroform. The success of the inflation of the lungs was, however, altogether owing to its being promptly performed. I have often opened the trachea of animals as quickly as I could after the breathing ceased from the effects of chloroform, and then performed artificial respiration, but without ever restoring them; for the short delay occasioned by having to open the trachea, has always prevented the success of the measure.

The only kind of artificial respiration that could be performed with sufficient promptitude, in cases of accident in the human subject, would probably be by applying the mouth to that of the patient, and either

inflating the lungs, whilst the larynx is pressed back against the oesophagus, to prevent the air from going into the stomach; or else drawing as much air as possible from the lungs of the patient by a strong inspiration, and allowing them to be filled again by atmospheric pressure. In cases such as that of J. Verrier, at Lyons, the case at Stockholm, and some others previously related, where the breathing continued a little time after the heart had ceased to act, it is probable that the heart is so overpowered by the chloroform as to be past recovery, otherwise the breathing would restore its action: however, it would obviously be right to continue the breathing by artificial means after it should cease; and either in these, or in any other cases in which the artificial respiration should not restore the patient in a minute or two, it would be desirable to open the external jugular vein, and allow some blood to flow, whilst still keeping up the artificial respiration. We have seen that the right cavities of the heart generally become distended with blood in death from chloroform, and this distension may obviously offer an impediment to its returning action. I have not succeeded in restoring any animal by opening the jugular vein after artificial respiration had failed; yet I have noticed in opening the chest immediately after death, that the feeble contractions of the heart which still continued, were improved in force and extent by opening a vein and relieving the distension of the right ventricle.

I have frequently tried to restore animals by electricity, but have never succeeded, except when it was probable that spontaneous recovery would have taken place. When the breathing has been arrested by the continued action of chloroform, and the heart has been still acting, electricity has always restored the animal; but, as was previously stated, spontaneous recovery is very apt to take place under such circumstances; a very little assistance in the way of artificial respiration is always successful; and, moreover, none of the accidents in the human subject have happened in this manner. When, however, the action of the heart has been arrested by chloroform, I have never succeeded in restoring animals by electricity. I have applied it by means of Neeves' electro-magnetic battery, sending shocks through the chest, and also applying one wire to the nostrils, or back of the neck, and the other near the insertion of the diaphragm, and breaking and renewing contact, so as to keep up some amount of respiration. Notwithstanding this want of success, electricity is one of the means which might be tried in case of accident to a patient; but it is obvious that the chief measure to be relied on is artificial respiration put in force very promptly, and that blood should be taken from the jugular vein, if the patient does not very quickly begin to show signs of returning animation.

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