to the auricles and the bases of the ventricles. The blood merely regurgitated in and out of the great veins.

In the tracing it is seen that after a time the effect of the chloroform passed off and the systole became more and more effective, whilst the dilatation steadily diminished until once more the trace reaches its former level and proceeds as before. The space between B and C represents 5 minutes 30 seconds.

In this experiment we were fortunate in administering a maximal non-lethal dose, but in several other traces of experiments in which the heart did not recover the trace rose in an exactly similar manner, but remained at the same level until the last feeble efforts of the heart gradually died out.

In Fig. 2 is shown the action of ether and A.C.E. for contrast with Fig. 1. At the point A, 5 minims of pure ether were injected into the external jugular vein and washed in with normal saline. This produced great but transient stimulation of the heart accompanied by a moderate degree of dilatation. Slight dilatation with increased beat persisted for a minute or so. This is in marked contrast to the diminished beat which follows chloroform (Fig. 1).

At the point B, 4 minims of A.C.E. were injected. The stimulation of the heart due to the ether and the alcohol is clearly shown, and it terminates at the point C, from which point the effect of the chloroform still persisted, and the dilatation tardily passed off.

We may add that a trace of the action of alcohol taken by the same method shows that this drug dilates the heart more than ether, but it stimulates its beat a little less. Its action persists about twice as long as ether but nothing like so long as chloroform. This effect of alcohol has previously been demonstrated by Newall and Smith.

It may not be out of place to restate the conclusions to which our experimental researches on the action of chloroform have led us. Chloroform acts upon three parts of the economy—(1) the heart, (2) the respiratory centre, (3) the arterioles. By its action on the arterioles chloroform does not produce directly fatal results, but inasmuch as it dilates these, it lowers the blood pressure and produces anæmia of the respiratory centre. This is a most important factor in regard to the stoppage of respiration. Failure of arteriole constriction can be remedied by elevating the abdomen or compressing it, and by lowering the head. By these means the supply of blood to the respiratory centre is improved.

The action of chloroform upon the respiratory centre is twofold. It is partly indirect, as we have just stated, and partly a direct action of the chloroform itself upon the centre. Arrest of respiration will be most easily produced when both these conditions of anæmia and chloroform act together on the centre. If the centre be much damaged by anæmia far less chloroform will arrest its action than when it is well supplied with blood.

And both these conditions are present during prolonged anaesthesia. This is the explanation of death from respiratory failure after chloroform has been administered for some time. Partly from the shock of operation, partly from the prolonged action of chloroform on the heart and arterioles, the circulation through the respiratory centre has been ebbing and ebbing, until the centre is no longer able to bear up under the degree of anæmia so produced, combined with the depressing effects of the amount of chloroform which happens at that moment to be administered. Thus the respiration ceases.

But fortunately we can reproduce artificially all the functions of respiration. The lungs can be ventilated; the chloroform thus escapes from the body; the blood is drawn into and driven from the thorax by artificial respiration. When the blood pressure rises in the respiratory centre, and the chloroform circulating in the blood disappears, then the centre recommences work. Cessation of respiration late in an operation is very seldom a fatal event. This is borne out by statistics, and must be the experience of every clinician.

But the action of chloroform upon the heart is a much more serious matter. When chloroform dilates the cavities of the heart, the power required to empty them increases as the cube of their radius, yet at the same time the power of the poisoned muscle is directly diminished. There are thus two factors acting in the arrest of the heart: (1) the distension of its cavities and (2) the direct weakening of its muscle. We have shown that when there is great distension a very

small dose of chloroform will be sufficient to arrest the heart. On the other hand, when a heavy dose of chloroform has been administered, it requires but a slight distension to produce the same result. This distension may be produced by accidental pressure on the abdomen, by efforts at artificial respiration, by inverting the patient as recommended by Nelaton. We have opened the chest of an animal and have observed a chloroformed heart to start and stop beating repeatedly, according as we placed the animal vertically feet down and emptied the right heart into the veins of the belly or vertically head down and distended it from them.

Both distension and overdose are present in typical cases of death occurring early in chloroform administration. The patient, often alcoholic, by struggling and holding his breath engorges his right heart. The anaesthetist to limit his struggles pours an excess of chloroform upon the mask. At last the patient gives in and takes deep gasping inspirations of air very highly charged with chloroform vapour. The first rush of blood through the lungs arrives in the left ventricle charged with chloroform, and is distributed by the coronary arteries to a right heart which is still labouring with distended cavities. The heart stops paralysed and dilated. The blood pressure rapidly falls to zero, and this sudden anæmia of the respiratory centre may cause a few gasping inspirations, followed by respiratory paralysis. Nor have we any efficient substitute for the cardiac systole. We can relieve the right heart by sitting the patient up. We may be able to excite the heart to contract by rhythmical compression through the chest wall. In dogs these methods sometimes succeed, but the time is very limited; and the statistics previously quoted by us that out of 41 deaths from chloroform 39 were of this early type show the extreme fatality of this accident.

This is the clinical picture of the danger of administering even moderate doses of chloroform to a distended heart.

The converse danger of distending a deeply chloroformed heart is, we believe, the explanation of those few cases of arrest of respiration late in anaesthesia which do not recover. The respiratory centre has, for the reasons we have stated, ceased to work, but the heart, though weak, is still able to carry on the circulation. But the cessation of respiration excites the anaesthetist to employ vigorous but ill-judged efforts to restore it. Perhaps he inverts the patient, or carries out a rapid and violent artificial respiration. These measures distend the right heart, which stops at once. The circulation is arrested, and this sudden and total anæmia of the respiratory centre excites those one or two solitary respirations which lead to the vain hope that the patient is about to recover.

In our opinion, as long as the heart beats efficiently there is very little risk that respiration will be permanently arrested. The horizontal position should be maintained, though the head may be lowered to encourage the medullary circulation. The tongue should be well drawn out, and an efficient artificial respiration carried out without undue haste or violence. Lastly, ether, alcohol, or strychnine may be injected hypodermically to stimulate the weakened heart.

NOTES.

¹ All operative procedures were carried out under chloroform anaesthesia, whilst observations were made during a constant condition of morphine narcosis. ² The idea of taking cardiographic tracings of the heart was first suggested to us by Mr. C. Wall, B.A., of the London Hospital, to whom we are greatly indebted both for this and other suggestions and criticisms.

A CASE OF CHLOROFORM POISONING IN WHICH NEARLY HALF A GRAIN OF STRYCHNINE WAS INJECTED: RECOVERY.

REPORTED BY SURGEON S. T. REID, R.N.

[Communicated by the DIRECTOR-GENERAL OF THE MEDICAL
DEPARTMENT OF THE NAVY.]

THE patient (an officer on board one of the merchant vessels in Malta Harbour) was found at 6.30 p.m. in his cabin by the captain and second officer of his ship, who noticed a strong smell of chloroform. He was at that time able to stand upright and answer the captain in semi-unconscious condition. He then fell forwards and vomited.

Coffee was given, artificial respiration resorted to, and the electric current brought into play, also shortly afterwards π xx of liq. ammoniæ were injected, by local medical man.

On the arrival of the ship's surgeon (8.30 P.M.) he found the patient deeply comatose, eyes suffused, face purple, breathing very slow and shallow—sighing—character, pulse just perceptible (40 per minute). He injected π xx of ether and gave an inhalation of nitrite of amyl, but finding no response to these he injected one eighth of a grain of strychnine and placed the patient in reclining position with feet well up.

I arrived shortly after, having been sent for, and as the patient was still in the same state—fully dilated pupils, loss of conjunctival reflex, relaxed sphincters—we determined to push the injection of strychnine to the full extent.

9.15 P.M. Injected $\frac{1}{4}$ gr. strychnine.

We increased the electrical current from 30 volts to 40 volts and the effect was very marked upon the respiratory muscles. Previously they had ceased to act, and respiration, which was very shallow and diaphragmatic, now became quicker and deeper, and the chest wall, commencing about the sub-clavicular regions, began to move with normal rhythm. But it was noticed afterwards that this marked effect of the current was only on suddenly increasing the strength, and not a continued stimulus that could be depended upon to keep the patient alive while the chloroform was being exhaled from the lungs.

The nape of the neck was shaved, and one pole (from the arrangement of the battery it was impossible to tell which was the anode and which the kathode) was applied as near the respiratory centre as possible, the other at the ensiform cartilage; finally the current was increased to 50 volts.

Artificial respiration was continued, and another injection of strychnine was given ($\frac{1}{2}$ grain at 9.40 P.M.). Shortly after this the effect of the drug became evident, chest respiration became more marked, trismus, pupil contracted. Conjunctival reflex was obtained, and it was noticed that the patient vomited after each fresh injection of strychnine. But what was most interesting was to see the gradual counteracting influence of the chloroform over and above that of the strychnine. The respiration again became shallow and diaphragmatic in character; the conjunctival reflex was no longer obtained, and the wedge of wood used to counteract the trismus fell out of the patient's mouth, while his aspect presented very little to suggest that he had had nearly one-third of a grain of strychnine injected, and a 50 volt current passing into him.

10.30 P.M. Injected $\frac{1}{2}$ gr. of strychnine.

11.30 P.M. Do. do. do.

The same course of events followed each of these injections of strychnine, but it was not till half an hour after the last injection that we got full evidence of the action of strychnine. On occasions he would have muscular contractions which necessitated stopping the artificial respiration and even holding the patient down on his couch, but these were not at all excessive and on reducing the electrical current, subsided almost completely. An hour after the last injection it was noticed that the strychnine still seemed to have strong influence, appearing as though we had injected just sufficient to counteract the influence of the chloroform, for the pupil still remained contracted; the conjunctival reflex was easily obtained, while the rigidity of the jaws subsided, and we had no other signs of excessive muscular contraction.

Twenty minims of tinct. digitalis had been injected with marked improvement of the circulation; heart sounds were now heard distinctly, pulse was felt at the ankle, and there was marked improvement of the pulse at the wrist. The respiration had greatly improved, the chest muscles were acting well, the inspiration was deep and long, and the patient continued to improve, till shortly after 1 A.M. he became sensible, having been under the influence of chloroform for over seven hours.

There were no other signs of the effects of strychnine; he had a very quiet night, dozing peacefully; his pulse was very weak, for which caffeine citrate was injected, and the next day he had slight diarrhoea, but the subsequent progress was very favourable.

REMARKS.

1. A stomach pump was not used at all; he had vomited freely after he was discovered (6.30 P.M.), and when the

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stomach pump was obtained, there was no smell of chloroform in the vomit, but his breath was fully impregnated with the odour, and continued so for fully twenty-four hours afterwards.

2. The quantity of chloroform taken into the stomach must have been over 2 ozs., but the quantity absorbed into the system can only be judged by the amount of strychnine injected and the length of time the patient continued to expire the vapour.

3. The tabloids of strychnine were used, strength $\frac{1}{50}$ gr.; of these 22 were used, making the total just under the half-grain.

CONCLUSIONS.

1. The great value of strychnine as a stimulant to the respiratory centre during chloroform poisoning in keeping life going while the vapour is being exhaled, but the drug must be used boldly.

2. The use of the electrical current in acting upon the respiratory centre at once, and by increasing the current rapidly, keeps the respiratory mechanism during the dormant stage of strychnine after injection.

3. With these two agents to hand one ought to be able to treat any case of chloroform poisoning.

MEMORANDA:

MEDICAL, SURGICAL, OBSTETRICAL, THERAPEUTICAL, PATHOLOGICAL, ETC.

RESPIRATORY OBSTRUCTION DUE TO ELONGATED UVULA IN CHLOROFORM ADMINISTRATION.

WHEN re-reading Dr. F. W. Hewitt's work on *Anæsthetics* recently I noted that in the section on preliminary examination of the patient the author does not mention a routine examination of the pharynx. My apology for presuming to mention the matter is a little experience that I had last winter.

In my capacity of House-Surgeon to Professor George Buchanan in the Western Infirmary, Glasgow, I had occasion to chloroform a male patient, aged 67, upon whom inguinal colotomy was about to be performed for malignant disease. Apart from the local abdominal condition, the patient appeared to be in fairly good health. Physical examination of the chest revealed no abnormality in heart or lungs. Respiration appeared to be normally performed, and articulation was distinct. The patient had no artificial teeth.

In these circumstances I proceeded to chloroform the patient as we usually do by means of a towel folded and tied with tape to form a mask, the chloroform being in a stoppered glass drop-bottle. The chloroform was administered very gradually, and well diluted with air. There was no coughing or struggling, and no apparent holding of the breath. The patient seemed to be taking the chloroform well. But, just as he appeared to be passing under and when the conjunctival reflex was becoming less active, there was a sudden stoppage of respiration with rapid development of cyanosis. When the chloroform was withdrawn breathing speedily became normal, but any attempt to continue the administration resulted in a recurrence of the previous symptoms.

Upon the first appearance of respiratory difficulty I hitched forward the lower jaw. This proving ineffective, the tongue was pulled forward by means of forceps. Still, there was no improvement. Though there was no evidence of excessive salivation or of mucous accumulation in the pharynx, the latter was swabbed out. Every attempt to continue the chloroform was followed very speedily by the previous difficulties.

It then occurred to me to make a more thorough examination of the fauces. With this object I opened the mouth widely with a Mason's gag, and turned the patient's face towards the light. I then discovered a remarkably long uvula, its lower extremity hanging far down towards the glottis. By means of a pair of artery forceps I seized the tip of the uvula, and held it forward. Without much strain being put upon it, the tip of the uvula, when so held forward, all but reached the upper incisor teeth. The case appearing to me an unusual one, I drew Professor Buchanan's