REVIEW ARTICLE

TRICHLORETHYLENE ANAESTHESIA

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TRICHLORETHYLENE was first described in 1864 by Fischer,[1] the German chemist. In the early part of the twentieth century it came to be widely used as a grease solvent in industry, and the occurrence of toxic manifestations in some workers exposed to the vapours aroused the interest of the German medical profession. In 1915, Plessner [2] described the syndrome of acute trichlorethylene poisoning to the Berlin Medical Society. It was characterized by vertigo, nausea and vomiting, and analgesia in the distribution of the trigeminal nerve. This last manifestation persisted long after the acute symptoms had abated.

It was suggested [3] that trichlorethylene had a specific action on the sensory roots of the trigeminal nerve, and that it might be of value in the treatment of trigeminal neuralgia. Several papers [4, 5] appeared on the treatment of this condition with trichlorethylene inhalations, but only in 1931 was a possible central narcotic action postulated.[6]

The effects of trichlorethylene had been studied in animals as far back as 1911, when Lehmann [7] anaesthetised cats for periods of up to five hours with recovery. Joachimoglu [8] also administered trichlorethylene to dogs without producing toxic effects.

In 1934, Jackson [9] in Cincinnati became interested in the central analgesic actions of trichlorethylene. He administered the drug to dogs from an inhaler of his own design. Some dogs were deliberately killed by an overdose of trichlorethylene, and Herzburg [10] was unable to find evidence of tissue damage when he examined the organs macroscopically and microscopically. On the basis of these studies, Striker and his co-workers at Cincinnati [11] administered trichlorethylene as an inhalation anaesthetic to 304 patients undergoing minor surgical procedures. All were short operations, and in many a state of analgesia only was achieved. The Cincinnati group believed that trichlorethylene would be a useful drug, but a report of the Council on Pharmacy and Chemistry of the American Medical Association [12] was discouraging, suggesting that more work was necessary to prove the safety of trichlorethylene, and interest in the drug as an anaesthetic agent lapsed.

The circumstances leading up to the clinical trial of trichlorethylene in London in 1940 has been graphically described by Ostlere.[13] At that time the Joint Anaesthetic Committee of the Medical Research Council and the Royal Society of Medicine were trying to find a non-explosive, safe substitute for chloroform for use on the battlefield. A Mr. Chalmers, a chemist living in London, was at the same time interested in trichlorethylene. After inhaling trichlorethylene vapour himself to produce a state of narcosis, he wrote to the editor of *The Lancet* asking for further information. This letter was passed on to Hadfield, Secretary of the Anaesthetic Committee, and Hewer undertook a clinical trial of the drug. Chalmers supplied pure trichlorethylene to Hewer for some of the early cases, but appears to have taken no further part in the development of trichlorethylene anaesthesia.

Hewer [14] was able to give a preliminary report on 127 cases in 1941. The drug was administered from the chloroform bottle of the standard Boyle's machine and was compared with chloroform as an adjuvant to nitrous oxide and oxygen, in a semi-closed system. Hewer used trichlorethylene for most of the common major operations for periods up to three hours, and in age groups from 14 months to 81 years. By 1942 Hewer [15] was able to report on 400 cases, and a year later on 3,700 cases.[16] Elam [17] also reported favourably on 1,000 cases in 1942. From this time on trichlorethylene was established in clinical anaesthetic practice.

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Physical Characteristics of Trichlorethylene. Trichlorethylene is a colourless volatile liquid, with an odour resembling that of chloroform. Commercial preparations may contain toxic impurities and only the purified agent should be used for anaesthetic purposes. In England, trichlorethylene is manufactured under the name "Trilene." Thymol 0.01 per cent is added to retard decomposition, and 1 in 200,000 waxoline blue so as to readily distinguish it from chloroform. In the United States, purified trichlorethylene is available as "Trilene" and as "Trimar." The pure drug tends to decompose in strong light and in air. It should therefore be stored in stoppered cans. Some glass vapourisers are tinted to protect the drug from light, but trichlorethylene should never be used after standing for more than a few days outside its normal container. If decomposition is suspected, it is an easy matter to test for the presence of free acid with a suitable indicator, or free chloride with silver nitrate or cadmium iodide and starch.[18]

The boiling range of trichlorethylene is 87.4 to 87.55 C. It is thus one of the least volatile of the inhalation agents, and for this reason open drop administration is unsatisfactory. It is not freely soluble in water but is soluble in organic solvents. It mixes with ether and chloroform without organic change. Thrichlorethylene has a special affinity for haemoglobin, but this relationship does not hold for whole blood. Powell [19] found the distribution coefficient between whole blood and air to be 18–22 at 20 C. and 7.8–10 at 37 C.

Trichlorethylene will ignite in concentrations of 10.3 to 64.5 per cent in oxygen or oxygen-rich mixtures, at a temperature above 25.5 C. This is a concentration of trichlorethylene well above that used in clinical practice. Small amounts of phosgene may be produced by the cautery,[20] but this is negligible in clinical practice.[16]

Trichlorethylene is always administered by inhalation, though it has been injected subcutaneously and intravenously in animal toxicologic studies.[21] Barsoum and Saad,[22] in experiments to find the minimal lethal dose, injected trichlorethylene intravenously, diluted five times in olive oil. They found that death occurred due to respiratory arrest. The heart continued to beat as long as oxygenation was maintained.

In England, the chloroform bottle of the standard Boyle's machine has been most commonly used as a vapouriser, in association with a semi-closed Magill system with a high flow of nitrous oxide and oxygen. The setting of the control lever is required at a much lower level than with chloroform. Mapleson [23] has investigated the concentration of trichlorethylene vapour obtained with such an apparatus, and found it to be never more than 1.5 per cent (v./v.) if gases are not bubbled through the liquid, but up to 3 per cent if they are. Ostlere [13] recommends that a concentration of 2.5 per cent be never exceeded, and Orth and Gillespie [24] say that a concentration of 0.75 per cent to 1.25 per cent is sufficient to produce surgical narcosis. Vapourisers designed for analgesia without loss of consciousness are usually set to deliver a concentration between 0.35 and 0.6 per cent.

The concentration of trichlorethylene in tissues has been determined by the Fujiwara reaction, and in recent years newer techniques [25-28] have been developed, including the "iodine-pentoxide-train" method.[29] In dogs Kulkarni [30] found a blood concentration of 20–37 mg. per cent during anaesthesia and a lethal concentration of 100–110 mg. per cent. In humans, Powell [31] has found a concentration of 6.5–12.5 mg. per cent during clinical anaesthesia and a concentration of 10.1–12.5 mg. per cent in those subjects exhibiting tachypnoea. She found the blood concentration to fall to 1 mg. per cent within three hours of cessation of anaesthesia and to 0.1 per cent in 24 hours. Trichloracetic acid appeared in the urine during the first 24 hours in a concentration depending roughly on the amount of trichlorethylene given. The trichloracetic acid levels increased for two days, and in a further five days had fallen to half the peak level. Thus it is apparent that not all the trichlorethylene is excreted by the lungs. Some is metabolised and excreted in the form of trichloracetic acid.[32] This latter compound has no pharmacological action.

Toxicity. As far back as 1910, Veley [33] compared the effects of trichlorethylene and chloroform on muscle stimulation. He found that trichlorethylene was 1.5 times more toxic than chloroform, molecule for molecule, and 1.36 times more toxic weight for weight, but

that recovery from trichlorethylene was more uniform. Many workers have administered trichlorethylene to animals without signs of toxic effects.[7, 8, 10, 34 36] Others have found some changes in liver function tests and hepatic cellular changes.[21, 22, 24, 37]

Liver Damage. Because of the similarity in chemical formula between trichlorethylene and chloroform, it might be feared that the former drug would also cause liver damage. Stuber [38] in a study of 284 cases of industrial poisoning from trichlorethylene found no evidence of liver damage in any of the patients. Hunter [39] reviewed the few cases of hepatitis and jaundice reported after industrial exposure and concluded that trichlorethylene was not the causative agent.

Armstrong [40] studied the cephaline-cholesterol flocculation test in association with trichlorethylene and ether anaesthesia and found little difference in results between the two. Brittain [41] found no evidence of liver or kidney damage in 250 neurosurgical cases undergoing prolonged trichlorethylene anaesthesia. In the first few years of trichlorethylene anaesthesia five cases of acute necrosis of the liver, thought possibly to be due to the drug have been described,[42-45] although a direct relationship to trichlorethylene was not established, except in two cases where cranial nerve palsy also occurred following the use of trichlorethylene in closed circuit.[45] Clinical experience since then has shown that hepatic complications from trichlorethylene are not to be feared. Blood sugar is little affected by trichlorethylene,[14, 34, 46] though acetonuria is a common finding.

Trichlorethylene and Soda Lime. In 1943, as the use of trichlorethylene in anaesthesia was increasing, some cases of cranial nerve palsy were reported [47] following its administration. At first it was shown [16] that contamination of trichlorethylene had occurred, but as more cases were reported,[48-51] it became apparent that this was not a full explanation. Some of the cases occurred on the same day in the same hospital. Some did not receive any trichlorethylene. But all had been anaesthetised with the closed circuit apparatus. Morton [52] and Humphrey and McClelland [48] suggested that trichlorethylene might decompose in the presence of soda lime to form a toxic product, and it has been found that dichloracetylene is produced.[48, 50, 53, 54]

$$\begin{matrix} CHCl \\ \| \\ CCl_2 \end{matrix} + NaOH \longrightarrow \begin{matrix} CCl \\ \| \\ CCl \end{matrix} + NaCl + H_2O$$

Dichloracetylene is now accepted as the cause of the cranial nerve palsies. The fifth and seventh cranial nerves have been most commonly involved, but also the third, fourth, sixth, tenth and twelfth. Many of the cases were associated with stormy recovery from anaesthesia as evidenced by headache and severe nausea and vomiting. Two fatal cases of encephalitis occurred among the reported cases.

Dichloracetylene is formed by decomposition of trichlorethylene in the presence of alkali and heat. It is itself spontaneously flammable to form phosgene and carbon monoxide. But this decomposition is retarded by the presence of excess trichlorethylene and ether, and dichloracetylene may linger within the apparatus to affect another patient on a subsequent occasion, perhaps as long as three days later.[49] At the same time a patient who has received trichlorethylene in the immediate past may exhale the drug into soda lime to form dichloracetylene. Ostlere [13] has described such a case in a woman who had trichlorethylene analgesia during labour, and was then anaesthetised with cyclopropane in closed circuit, only to develop a cranial nerve palsy postoperatively. Animal experiments [55] suggest that this hazard is much diminished if air is breathed for as little as 15 minutes after trichloroethylene anaesthesia or analgesia.

The amount of dichloracetylene produced increases as the temperature rises in the soda lime canister. But the relation is not linear. Firth and Stuckey [54] found the rate of formation of dichloracetylene to be small at room temperature, but to rise sharply above 60 C., a temperature reached in the canister with the brands of soda lime used in 1943. These brands contained more sodium hydroxide and generated more heat than the brands in use today. Kilpatrick [56] has shown that temperatures much above 40 C. do not occur with good quality soda lime, although some dichloracetylene is produced.[55] Addition of sil-

ica to soda lime also retards the decomposition of trichlorethylene.[57]

Although the chances of cranial nerve palsy following trichlorethylene anaesthesia with soda lime is more remote today, all authorities advise against its use in closed circuit.

The Cardiovascular System. Blood pressure is unchanged by trichlorethylene [14] and increased capillary oozing at the operation site does not occur.[15] The main changes of concern to the anaesthetist are the effects on cardiac rhythm.

All the early reports of trichlorethylene anaesthesia show an incidence of cardiac irregularities.[14, 58, 63] The incidence varies from one author to another, and is usually small as detected by palpation of the pulse, but high when electrocardiographic monitoring is employed.[64]

Barnes and Ives [64] made a thorough electrocardiographic investigation in a series of 40 normal patients undergoing trichlorethylene anaesthesia. They found changes in the electrocardiogram in 33 of these patients. Those occurring in light anaesthesia included bradycardia and shift of the pacemaker towards a nodal rhythm, and were ascribed to increased vagal tone. In deeper anaesthetic planes ventricular extrasystoles and multifocal ventricular tachycardia occurred in some cases. Barnes and Ives concluded that these latter arrhythmias were of serious import and believed that trichlorethylene should not be used as a routine adjuvant to nitrous oxide in clinical practice, particularly if adrenaline was to be used in any part of the surgical operation.

It would be expected that adrenaline infiltration in the surgical field would increase the incidence of arrhythmia and even cause ventricular fibrillation. In dogs, intravenous injection of adrenaline during trichlorethylene anaesthesia produces ventricular extrasystoles and multifocal ventricular tachycardia.[59] However, in clinical practice subcutaneous infiltrations of dilute solutions of adrenaline have not been followed by cardiac collapse.[13, 76] Lloyd-Williams and Hewspear [60] have reported a case of atrial fibrillation associated with infiltration of 1 : 150,000 adrenaline solution into the neck. Hewer [77] has warned against the use of too strong a solution, and recommends a dilution of 1 : 500,000 which produces a good vasoconstriction if sufficient time is allowed for it to act.

There are reports [13, 46, 65–72] of sudden acute cardiac failure occurring during trichlorethylene anaesthesia and of deaths during or following the use of trichlorethylene. In some it is possible that true primary cardiac arrest has occurred, although in others it is unlikely since collapse occurred after the end of anaesthesia.[73, 74, 75]

Opinion is divided about the safety of trichlorethylene. Some believe it to be too dangerous for routine clinical use.[58, 64, 71] Others believe that if trichlorethylene is given carefully without overdosage the incidence of serious complications is very low. Hewer [78] has warned against placing too much emphasis on electrocardiograms in the evaluation of new anaesthetic drugs, pointing out that cyclopropane might never have achieved popularity if too much attention had been paid to electrocardiography.

With the passage of time, several writers have reported series of patients given trichlorethylene without mishap.[79, 80, 81] Scragg [82] has reported 30,000 maternity cases given trichlorethylene as the principal agent with no maternal deaths attributable to anaesthesia. Hewer [83] has recently reported a series of 60,000 trichlorethylene administrations from St. Bartholomews Hospital with three cases of possible primary cardiac failure. (The first case occurred during wartime conditions. A student was supervising the anaesthesia when death suddenly occurred. The second was directly related to injection of 1 : 250,000 adrenaline. There are no data available on the third case.)

Respiratory System. Trichlorethylene vapour is only slightly irritant to the respiratory tract, although premedication with a belladonna drug is recommended.[13] During induction, reflex coughing and laryngospasm can be avoided if the vapour strength inhaled is increased gradually.

Trichlorethylene characteristically causes an increase in the rate of respiration. This has been noted in early animal experiments [7] and in early reports of human anaesthesia.[11, 14] In a series of 105 neurosurgical cases, Ayre [84] found a respiratory rate above 30/minute in 44 per cent. Similar observations were made

by Dundee [85] in a series of 437 patients. He found that tachypnoea was more common in children and old people, and that the incidence was increased when a higher concentration of trichlorethylene was inhaled. In some cases tachypnoea occurs early, in light anaesthesia, especially in relation to surgical stimulation. Tachypnoea can be countered by the administration of suitable doses of a narcotic, such as meperidine, and by lowering the vapour concentration of trichlorethylene.

As tachypnoea develops the respirations become more rapid and shallow. Dundee and Dripps [86] have studied the relationship of tidal volume, respiratory rate and minute volume. Shallow respirations are less efficient in terms of gaseous exchange, as the anatomical dead space comes to take up a greater proportion of the tidal volume. Dundee [85] found a fall in arterial oxygen saturation of 25 per cent as the respiratory rate became double the normal, even though minute volume had risen.

Whitteridge and Bulbring [87, 88] have investigated the cause of the tachypnoea by studying the electrical changes in the vagus nerve of the cat. They suggest that trichlorethylene acts peripherally in the lung, probably by stimulation of deflation-reflex fibres to curtail expiration and stimulation of stretch-reflex fibres to shorten inspiration. Dundee [85] has investigated a suggestion that the mechanism is one of bronchoconstriction which can be relieved by meperidine. He found that whereas meperidine and morphine consistently slow the respiratory rate, various bronchodilator drugs do not. Meperidine probably acts by central depression of the respiration centre and by depressing the Herring-Breuer reflex.

Muscular Relaxation. Trichlorethylene does not produce good relaxation of the abdominal muscles, and it is not satisfactory for intra-abdominal procedures unless combined with a muscle relaxant.[89] It is never justified to "push" trichlorethylene in an endeavor to obtain muscular relaxation.

In combination with muscle relaxants there is a tendency for tachypnoea to develop, and the short jerky respirations resulting are often difficult to assist. Use of carbon dioxide absorption is contraindicated and the control of respiration is not facilitated. For these reasons trichlorethylene is not a convenient agent for intrathoracic surgery. There are no reports of synergism or antagonism between trichlorethylene and the muscle relaxants.

Tracheal intubation can sometimes be achieved using trichlorethylene as a supplement to nitrous oxide, but it is often not easy unless a high concentration is delivered or else a supplementary dose of thiopentone given just before attempted intubation.[90]

Clinical Use. When first introduced trichlorethylene was compared to chloroform and other inhalation agents. But it soon became apparent that only Plane 1 of Stage III of Guedel's classification could be obtained safely, and that if deeper planes or muscular relaxation were required, resort must be had to other agents. The nitrous oxide-oxygen mixture was used mainly as a convenient method of vapourising the volatile liquid, although it was recognized that the weak anaesthetic action of nitrous oxide lessened the amount of volatile anaesthetic required.

Rees and Gray [91, 92] have described the triad of anaesthesia, which they divide up into hypnosis, analgesia and relaxation, and it has become apparent that the analgesic effect of nitrous oxide in this context is not inconsiderable. A trace of supplementary agent, such as trichlorethylene, added to nitrous oxide, after thiopentone induction, is all that is required for a wide range of surgical operations. The marked analgesia produced by even a low concentration of vapour, makes trichlorethylene a drug particularly suited to this role. Moreover, using trichlorethylene in minimal concentrations means that the likelihood of toxic complications is diminished.

The use of trichlorethylene for its analgesic rather than its anaesthetic action means that it is rational to compare it with other agents commonly used as a supplement to thiopentone-nitrous oxide anaesthesia. These include the narcotic drugs, the phenothiazine derivatives, the use of incremental doses of thiopentone, and minimal ether. Trichlorethylene exhibits several advantages in such a comparison. Severe respiratory and circulatory depression do not occur. Blood pressure is stable, and serious arrhythmias are uncommon with the small concentrations used. The technique is non-explosive.

If tachypnoea develops it responds readily to the judicious administration of meperidine, or related compound, given intravenously. Doses of the order of 10 mg. meperidine will often cause a slowing of respiratory rate, and can usually be repeated if necessary. It is difficult to state dogmatically at what respiratory rate tachypnoea begins–generally speaking, rates above 35/minute in an adult are undesirable, though a mild degree of tachypnoea is usually tolerated well for a short period. Sudden severe bursts of tachypnoea are sometimes associated directly with surgical stimulation–as in retraction of a nerve root. It is unwise to treat such tachypnoea with a narcotic, or respirations may be unduly depressed when the surgical stimulus is over.

It is rational to include morphine or meperidine in the preoperative medication so that tachypnoea does not occur so readily. Lack of suitable premedication, or absence of thiopentone induction means that too high a concentration of trichlorethylene may have to be employed so that tachypnoea and cardiac arrhythmias are more likely to occur.

Trichlorethylene is excreted relatively slowly and recovery from anaesthesia is slower than with other inhalation agents. This seeming disadvantage can be obviated if the vapouriser is switched off before the end of operation.

Trichlorethylene is a cheap drug, and only a small amount is used for the average case. The main cost of trichlorethylene anaesthesia is in the high flow rate of nitrous oxide and oxygen required for anaesthesia without carbon dioxide absorption.

Experience at St. Bartholomews Hospital has shown that trichlorethylene is a convenient and safe agent for a wide range of surgical operations. It is used for most operations on the head and neck and extremities, including intracranial surgery,[90] otolaryngological surgery,[93] and orthopaedics. It is less convenient when used for abdominal or intrathoracic surgery for the reasons stated. Children are apt to develop tachypnoea unless heavily premedicated. In those with pre-existing cardiac arrhythmia it would seem wise to use another agent.

Trichlorethylene in Obstetrics. Trichlorethylene has been widely used for the production of a state of general analgesia without loss of consciousness since Elam[17] in 1942 suggested that this would be a valuable method for relief of pain during labour.

Trichlorethylene has no effect on uterine function.[15] Helliwell and Hutton[94] have shown that it readily crosses the placental barrier to reach the foetal circulation of sheep and goats. Taylor, *et al.*,[95] however, found no changes in arterial oxygen saturation of the newborn after trichlorethylene analgesia compared to significant falls where meperidine had been used.

In England, the practice of entrusting care of a woman in labour to a midwife has meant that only limited techniques are available for relief of pain in labour. Midwives were allowed to use only limited doses of meperidine and a nitrous oxide-air mixture from an approved type of apparatus. Trichlorethylene and other methods could only be used when a physician was in attendance. Seward[96] examined the value of trichlorethylene in obstetrics, finding that it was satisfactory when given as 0.5 per cent concentration in air, and superior to nitrous oxide-air as used by midwives. Trichlorethylene has been given from a variety of apparatus.[97–103] Among the most popular have been Freedman's inhaler,[104] the Cyprane and Duke inhaler. The desire to make trichlorethylene available for administration by midwives has led to the development of special inhalers[105] to give a known concentration of vapour under all conditions of use. The various reports of successful use of trichlorethylene has finally led the Committee on Analgesia and Midwifery of the Medical Research Council[106] to recommend that midwives be allowed to use trichlorethylene from certain approved types of inhaler, not to exceed a concentration of 0.5 per cent.

Experience has shown that several seconds are required from the time of commencement of trichlorethylene inhalation until peak analgesia is achieved. Inhalation should therefore begin as soon as the uterine contraction commences. An intelligent mother can learn to anticipate the uterine contraction so that maximal analgesia is obtained at the height of the contraction. Success with this method therefore depends on adequate instruction and a cooperative, intelligent patient.

Trichlorethylene Analgesia in Other Fields.

Trichlorethylene analgesia has been used for minor urologic procedures,[107, 108, 109] for gastroscopy,[110] in dentistry,[111, 112, 113] and in the relief of pain associated with malignant disease.[114] Bernstein [70] has reported a case of cardiac arrest during trichlorethylene analgesia for painful wound dressing in a nineteen year old man. The heart was re-started by cardiac massage, but there was still not full mental recovery one month later.

Trichlorethylene analgesia has been used by Brown and Fehlman [115] for a variety of minor surgical procedures, including incision of abscesses, manipulations, setting of fractures and burn debridement. While absolute pain relief was not achieved in every case, it is apparent that a wide range of procedures could be carried out under trichlorethylene analgesia if facilities for full general anaesthesia are not available.

The Author's Personal Appraisal of Trichlorethylene

Personal Technique. Trichlorethylene is used in the standard Boyle's machine using a semi-closed Magill system. In the United States a suitable apparatus is the Rowbotham vapouriser attached to outlet of a Heidbrink or Foregger machine (fig. 1). Trichlorethylene is used in combination with thiopentone and nitrous oxide for most cases where it is expected that assisted or controlled respirations will not be required. These include most operations outside the chest and abdomen. Trichlorethylene is relatively contraindicated where there is a pre-existing cardiac arrhythmia and in the presence of thyrotoxicosis, although I have never seen untoward reaction in these cases. Children exhibit tachypnoea more readily than adults, and so trichlorethylene is less satisfactory. But where there has been heavy premedication, where the child has first been "settled" with ether or where thiopentone induction has been used, minimal trichlorethylene can be used for maintenance. The average patient is premedicated with morphine 10 mg., or meperidine 100 mg. and scopolamine 0.4 mg., or atropine 0.6 mg., one to one and a half hours before induction. Anaesthesia is induced with thiopentone, and if tachypnoea is to be avoided something more than a sleep dose is usually required. A

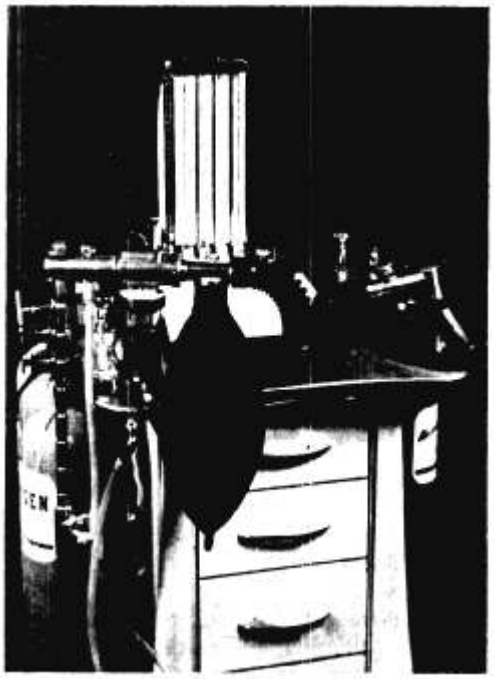

Fig. 1. Robotham vapouriser attached to anaesthetic machine for administration of trichlorethylene.

flow rate of about 2 liters/minute oxygen with 5–6 liters/minute nitrous oxide is begun using the Magill semi-closed system with pop-off valve near the face-piece. Trichlorethylene is then added carefully, increasing the concentration gradually with every 2–3 breaths. The smell of trichlorethylene in the vapours delivered gives the best indication of the amount of drug delivered, unless the anaesthetist is familiar with the settings on the machine. Induction is relatively slow and 10–15 minutes should be allowed before the operation is begun. Once the patient is settled, however, the vapouriser should be set so that enough trichlorethylene is delivered that the anaesthetist can just detect its presence by smell. If tracheal intubation is required, it is usually achieved with succinylcholine. Topical analgesia of the larynx, using a suitable spray, enables the endotracheal tube to be tolerated in a relatively light plane of anaesthesia.

Increasing respiratory rate can be countered by the administration of meperidine. The two agents, trichlorethylene and meperidine, can be used together satisfactorily. Both provide analgesia; whereas trichlorethylene increases

respiratory rate, meperidine decreases it. Generally speaking, a respiratory rate of between 20 and 30/minute can be achieved by using the two agents in partnership. Meperidine is given in doses of 10 mg. intravenously. A small dose can always be repeated, but larger doses can sometimes result in undue depression. Occasionally the cough reflexes are difficult to subdue, as when a patient reacts strongly to an endotracheal tube. A small dose of *d*-tubocurarine chloride (*e.g.*, 6 mg.) will often abolish these reflexes without having a significant effect upon respiratory tidal volume.

Depending upon how much trichlorethylene a patient has received, the vapouriser can be switched off before the end of operation. In this way a prolonged recovery from anaesthesia is avoided.

Trichlorethylene has been used in combination with relaxant drugs for intra-abdominal surgery. Although this method can be used successfully, the modern trend has been to use controlled respirations with carbon dioxide absorption.[9,2] In this way the anaesthetist has full control over ventilation, supplementation of nitrous oxide analgesia is often not required, and trichlorethylene is contraindicated because of the use of soda lime.

The Role of Trichlorethylene Today. New anaesthetic agents are constantly being introduced to anaesthesia. All of them possess both advantages and disadvantages. One of the seeming disadvantages of trichlorethylene is that its anaesthetic action is weak. Induction of anaesthesia is slow, and deep planes of anaesthesia cannot be obtained. Here, for example, is a big advantage for halothane which is potent, so that the patient can be quickly anaesthetised to the level of surgical anaesthesia. On the other hand, the potency of halothane is such that special vapourisers are recommended in order to prevent overdosage. Excessive trichlorethylene can be readily avoided without complicated apparatus. There is an inherent safety in the use of a weak anaesthetic agent, especially if it is used mainly for the stage of analgesia, which is so marked with trichlorethylene.

Tachypnoea is not a major problem if trichlorethylene is used according to the technique described. In small children and infants, however, access to a vein is sometimes difficult and trichlorethylene tachypnoea may then present a real problem necessitating change to another agent.

Trichlorethylene is one of the few non-explosive agents used to supplement nitrous oxide anaesthesia which does not produce significant respiratory depression. The various intravenous agents used all produce a degree of depression, and sometimes this is so marked that a satisfactory level of anaesthesia cannot be obtained without hypoxia and hypercarbia. The use of narcotic-antagonist mixtures may obviate these disadvantages, but they have yet to achieve wide popularity.

Serious cardiac arrhythmias are uncommon if minimal concentrations of trichlorethylene are used. If they do occur anaesthesia should be lightened or a change made to some other agent. The blood pressure and pulse rate usually remain remarkably steady during anaesthesia. Often the systolic pressure remains within 10 mm. of mercury over long periods, and gross changes are usually due to some factor other than trichlorethylene.

The author believes that clinical experience has shown trichlorethylene to be a safe and useful agent when used in minimal concentrations. The disadvantages originally described have been overcome with increasing experience. Those who are enthusiastic proponents of trichlorethylene will need convincing data to show that it can be replaced in clinical anaesthesia.

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