HAZARDS IN THE USE OF THE CLOSED-CIRCUIT TECHNIQUE FOR TRILENE ANAESTHESIA

BY

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Within the past two years trilene (trichloroethylene) has been increasingly used as a form of general anaesthesia. It has certain advantages over ether and cyclopropane, such as non-inflammability, and it is regarded as safer than chloroform, for there is much less risk of ventricular fibrillation. When diathermy is necessary, particularly in the region of the head and neck, trilene commends itself as a suitable non-explosive anaesthetic agent. As a rule I have limited my use of trilene to thyroid and breast operation cases. Its use in a closed-circuit machine appears to fall in line with what is almost a routine practice of most anaesthetists—that is, the carbon dioxide absorption technique for inhalational anaesthetics. There are many advantages of such a method, the outstanding one being that a quiet operation field is ensured by the diminished respiratory excursions. In cyclopropane anaesthesia this technique is of course essential for practical and economic considerations. The purpose of this paper is to show that it is dangerous to use trilene with a closed-circuit technique.

Illustrative Cases

Case 1.—Mrs. A., aged 67, a frail thin woman, was a poor risk for operation for stone in the hepatic duct. On Nov. 22, 1943, she was given premedication of omnopon gr. 1/6 and scopolamine gr. 1/300; then pentothal g. 0.5, followed by endotracheal cyclopropane. The operation lasted 1½ hours, during which she was given 750 c.cm. of plasma. No trilene was used in this case. The same apparatus, however, had been employed to administer trilene to a patient immediately preceding this one. In the evening following operation her temperature was 99° F. and she vomited repeatedly. This vomiting started 12 hours after operation and continued for three days, when she first complained of difficulty in swallowing and numbness over the face. She was seen by Dr. Wilfred Harris on Dec. 11, and I am indebted to him for the following neurological notes: "Slight diplopia in all directions. Left third nerve shows partial ptosis, and the left pupil is sluggish. There is bilateral slight weakness of both external recti, with homonymous diplopia. The voice is markedly nasal and there has been nasal regurgitation, and the right soft palate is obviously paretic. Fifth nerve:—There is total anaesthesia to pin-prick and even hand pressure over both first divisions, and the right second division, including the hard palate. The left second division is totally analgesic to pin-prick, but hand pressure is felt on the cheek. Moderate analgesia of third division on both sides, mostly on the right. Total motor palsy, with complete jaw-drop, is present. There is loss to taste over the right second division on the palate, but taste on both sides of tongue is fair."

This patient had to have a gastrostomy (under local anaesthesia) on Dec. 26 because of the inability to swallow. The gastrostomy tube was removed after five weeks (Jan. 31, 1944), and she is now swallowing food reasonably well. Although her general condition has vastly improved, the fifth and other nerve palsies show slight improvement only.

Case 2.—Miss B., aged 50; operation, Dec. 6, 1943—local excision of benign tumour of breast. Premedication, omnopon gr. 1/3, scopolamine gr. 1/150, pentothal g. 0.5 in bed were followed by a very short further induction with cyclopropane and by nitrous oxide, oxygen, and trilene, using the closed-circuit technique. The duration was only 20 minutes. About 12 hours after the operation vomiting started; this continued for 36 hours. On the evening of Dec. 7 the temperature was 99°, and lasted two days. In the early morning of Dec. 8 she complained of double vision, stiffness of the face, and difficulty in swallowing. Dr. Harris saw her on Dec. 11, and reported: "She has a bilateral third-nerve paresis, the right being practically complete. The right pupil is much dilated, with very little reaction to light or convergence. Fifth nerve:—She complains that the face feels hot and 'tingly' over both cheeks (second division). Nearly complete analgesia to pin-prick over first and second divisions of both sides, including conjunctivae, and upper gums and palate. No pain on pricking the inside of nostrils. No motor fifth-nerve weakness, the masseters and external pterygoids being strong. Little if any anaesthesia of the third division of fifth. Sense of smell good. She has no nasal regurgitation, the soft palate rises normally on phonation, and there is no analgesia of the pharynx; but there is a suggestion of slight palatal weakness, because she cannot blow out her cheeks properly." There has been only

very slight improvement in this patient eight weeks after the onset of the paralysis.

Both cases therefore showed well-marked bilateral trigeminal anaesthesia, oculomotor palsy, and also difficulty in swallowing, the latter symptom being more pronounced in Case 1.

In the first case the trigeminal paralysis was total for the upper two divisions, with a total motor fifth-nerve palsy. In this first case, too, the right half of the soft palate was completely paralysed (tenth cranial nerve), and though the oculomotor paralysis was less than in Case 2 there was additional weakness of both sixth nerves. Case 1 also showed scars of recent herpes on the right upper and lower lips, which strongly suggest that a "toxin" had affected the Gasserian ganglion. Dr. Harris pointed out that herpes frequently appears over the lips and nares after Gasserian alcohol injections.

Discussion

On making inquiries it was found that a case immediately preceding Case 1, on Nov. 22, had pentothal, nitrous oxide, oxygen, and trilene, via a closed-circuit machine, for the removal of an adenoma of the thyroid; this patient subsequently vomited a good deal and complained of giddiness. She was seen a few weeks later, but there was no evidence of her having had any paralysis. It is worth emphasizing that Case 1 did not have trilene, and it should be noted—an important fact—that the soda-lime canister was not changed between the cases. Case 1 would thus have been exposed to a prolonged inhalation of any toxic products that may have formed in the soda-lime canister when the trilene had been administered to the immediately previous case. The idea that a toxic product had formed in that canister was suggested by the fact that between the dates of the first case (Nov. 22) and the second (Dec. 6) eight others were given pentothal followed by cyclopropane anaesthesia with the same apparatus, and with no ensuing paralysis. It seemed an extraordinary coincidence that on the only two days that trilene was used a patient developed paralysis. Also it was noted that only recently at this hospital, for the convenience of dispensary ordering, a change-over had been made to another well-known brand of soda-lime (B). This appeared to give very good absorption clinically; but it was noticed that the canister became much hotter than with the previous brand, A (sofnol soda-lime). Another point with Brand B was that when it was necessary to change the soda-lime it was often found to be caked, and sometimes had to be dug out of the canister; whereas Brand A could always be easily shaken out. This led to the conclusion that Brand B, though it gave very good absorption, was the more hygroscopic. Accordingly, a full investigation, and analyses, of the soda-lime, trilene, and cyclopropane were started, and Dr. H. E. Cox kindly undertook the chemical analyses. Results of analyses of the two brands were:

	A (Sofnol)	B
Calcium hydroxide	84.1%	77.6%
Sodium hydroxide	1.2%	11.2%
Carbonate (calculated as Na ₂ CO ₃) ..	4.8%	5.4%
Moisture	7.4%	3.0%

Equal quantities of the two were then exposed in a moist atmosphere at room temperature, showing:

	A	B
Water absorbed after 18 hours ..	0.54%	2.23%
" " " 66 " ..	1.38%	6.77%

It will be observed that the clinical finding that Brand B has a greater avidity for water is confirmed. Also, it is particularly important to note that the caustic soda content of B is more than 9 times that of A. The significance of the latter point is discussed shortly. In his analysis Dr. Cox found no evidence of any deleterious substances in the cyclopropane or trilene; but experiment showed that, whereas when cyclopropane was passed through soda-lime no reaction occurred, with trilene through soda-lime a reaction took place, producing a distinctive sour smell. This reaction took place slowly at room temperature and rapidly at blood heat. As I have personally recorded temperatures of 110° F. using Brand A soda-lime and 178° F. when using Brand B in the canister of a circle absorber under conditions of anaesthesia, it will be readily understood that any chemical interaction will almost certainly be considerably speeded by this increased warmth. Trilene is itself very reactive, and is a derivative of acetylene, which chemically is one of the most reactive compounds

known. Dr. Cox also pointed out that trilene with soda-lime produces new and potentially toxic products, one of which is dichloroacetylene. This is easily oxidized to phosgene and carbon monoxide.

Trilene heated with alkali produces dichloroacetylene, and experiment shows a recognizable formation of this at even 98° F. If the heating is continued in the open, the dichloroacetylene, being very volatile, disappears, but if a condenser is used the dichloroacetylene accumulates and there is an explosion, producing phosgene. But when an excess of trilene vapour or an inert gas is maintained, dichloroacetylene does not further oxidize, and no explosion or phosgene formation occurs. This explains the fact that experimentally no phosgene reaction occurred in the circuit of the apparatus. The distinctive smell noted above is almost certainly due to the formation of dichloroacetylene, the physiological activity of which is at the present time unknown, and it is dismissed in all the literature as spontaneously explosive.

The fact that Brand B soda-lime is shown to contain more than nine times the amount of caustic soda, that it is more hygroscopic, and that it generates more heat under anaesthesia supports the clinical observation that this brand would definitely be more reactive towards trilene, with the production of toxic oxidation substances. This view is supported by the clinical evidence that no case of paralysis occurred while Brand A of soda-lime was used at the hospital; and no case occurred when employing my own apparatus for closed-circuit trilene anaesthesia, in which Brand A has always been used. The high temperature generated by Brand B soda-lime, and therefore of the inhaled anaesthetic gases, is of further disadvantage to the patient; it leads to excessive sweating and capillary engorgement (Hewer, 1942) even at 104° F.

Conclusion

The relatively low incidence of post-trilene paralysis is, according to the above facts, due to three factors:

1. Fortunately, the vast majority of administrations with this anaesthetic agent have been given in an open circuit. As there is no evidence of direct formation of oxidation products in the trilene without soda-lime, it seems that there is no apparent risk when trilene is used in an open circuit.

2. The high temperatures generated and recorded in the canister of a circle absorber during anaesthesia have been at the point of maximum intensity of reaction, usually after the soda-lime has been in use for about an hour. If the soda-lime has already been in use for some time we do not get these very high temperatures, which are an exciting factor in the oxidation of the trilene into toxic products.

3. The actual amount of caustic soda available for this chemical reaction with the trilene has been shown to be considerably higher in some brands of soda-lime. It appears to be the most important factor—apart from the rise in temperature—for this effect on the trilene.

McAuley (1943) describes three cases of bilateral trigeminal anaesthesia, and it is to be noted that in every case the closed-circuit technique had been used. Lengthy anaesthesia does not seem to be necessary for full toxic effect. In his cases the durations were 20 minutes, 30 minutes, and 1½ hours, and in one of my cases the anaesthesia lasted only 20 minutes.

Summary

Evidence is brought that trilene anaesthesia in a closed circuit is dangerous, and may result in trigeminal and other cranial-nerve palsies. The palsies are disabling and may be permanent.

This danger is shown to be due to toxic oxidation products formed by the interaction of soda-lime and trilene.

This reaction is speeded by the heat generated in the soda-lime.

The exact caustic soda content and hygroscopic properties are shown to vary in different brands. This, it is indicated, is an important factor in the occurrence of these cases.

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INTELLIGENCE AND SEASON OF CONCEPTION

BY

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Many studies have shown that there is an association between season of birth, or of conception, and intelligence. The evidence has recently been ably marshalled by Fitt (1941), himself the contributor of the most substantial body of data. Children whose time of conception is centred on the winter months are on the average somewhat more intelligent than those conceived during the other half of the year. After analysing the results of the various investigations, which naturally show a certain amount of difference in detail, Fitt selects for contrast (with suitable reversal in the Southern Hemisphere): (1) birth months May to October, corresponding approximately to conception months August to January; (2) birth months November to April, corresponding approximately to conception months February to July. Children falling into these two groups will for conciseness be described in this paper as winter and summer children respectively.

The Alternative Explanations

Two explanations of the difference are possible: first, that season of conception influences intelligence; or, secondly, that intelligence influences season of conception. Now, it is a remarkable fact that, with one partial exception (so far as I am familiar with the literature), every investigator has assumed without discussion that the first explanation must be the correct one. Some of the hypotheses advanced are outside the range of orthodox biological opinion—for example, that “the higher metabolic level of parental protoplasmic vigour during winter cold seems to be transmitted through the germ-plasm, and to exert a lasting effect upon the future course of the offspring.” There would seem to be nothing inherently unlikely, however, in the assumption that the prenatal environment of the developing child is more favourable at one season as compared with another. This would be an interesting addition to the list of known non-genetic prenatal influences, such, for example, as the well-known effect of advanced maternal age in mongolism, or the effect of being a first-born child in congenital pyloric stenosis (Cockayne and Penrose, 1943).

The partial exception to this unanimity of opinion is provided by Huntington (1938). His observations on such material as highly gifted persons have led him to postulate a favourable season which is different from that indicated by the large-scale studies. He is concerned to explain the discrepancy, and states (p. 325): “It seems highly probable that the three types here mentioned—namely, the passionate, the unintelligent, and the weak-willed—contribute more than their proportional share to the excess of births which still occurs at the height of the animal rhythm. We should expect many of the children of such parents to have low intelligence, and they might well suffice to overbalance the unusually bright children who are born at the same season, thus giving a low average I.Q.” In regard to his main thesis, however, he is convinced that it is season which affects intelligence. Thus he states (p. 441): “Our new knowledge as to season of birth can be of practical use only if we use it in one of two ways. First, we can change the present seasonal distribution of births. Secondly, we can discover the exact conditions which make certain seasons favourable, and then take steps to create those conditions at other seasons.”

Practical Importance of the Problem

Apart from the theoretical interest of the problem, the practical importance of deciding which explanation is the right one is not inconsiderable. Many writers carry their argument to its logical conclusion and urge that a planning of season of conception would aid in human betterment. To choose one example, Mills (1941) sums up as follows: “The findings reported in these pages have a very direct bearing