

CLOSED CIRCUIT ANESTHESIA UTILIZING KNOWN INCREMENTS OF HALOTHANE

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THE use of halothane in a closed circuit is desirable from the standpoint of economy. The method has, however, been stigmatized by the occurrence of severe hypotension, cardiac arrest and death.¹ Anesthetists have been admonished to avoid placing the halothane vaporizer in the circuit and, in particular, to avoid controlled ventilation.

Much of the difficulty stems from the lack of vaporizers which function reliably at low gas flows and whose output is not materially affected by changes in respiratory tidal volume. Interposition of a "copper kettle" or Fluotec in the gas inlet provides a means of adding reasonably accurate concentrations of vapor to the circuit. Another approach to accuracy is the addition of known quantities of agent at appropriate intervals. For this the drip-feed method has been suggested as being practical and economical.^{2, 3} We have altered it in a manner designed to combine simplicity of approach with safety of administration. This provides for the administration of increments of agent as needed, in many respects similar to the intermittent technique for administering cyclopropane in the closed circuit.

METHOD

Vaporizer. We noted that halothane vaporized quickly when dropped in amounts of 0.5 ml. or less on a metal screen, particularly when a current of air was drawn across the screen. Accordingly, we decided upon what is probably the simplest form of vaporizing device: a syringe containing halothane connected by a stopcock to a metal screen placed in the fresh gas inlet or in the circuit of respired gases. This principle was employed in the manufacture of a vaporizer (fig.

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1) which could readily be placed in the expiratory side of any conventional circle absorber.

Clinical Material. Three hundred patients, ranging in age from 3 to 84 years were anesthetized with halothane using the vaporizer in the gas inlet or in the circuit as described. The majority of the patients were in the fourth to sixth decades. Thirty-five were classified physical status III (A.S.A. Code). The remainder were I or II. Eight had had previous myocardial infarcts.

Minor surgical procedures (table 1) comprised slightly more than one-third of the series. The method was also utilized in a wide variety of major procedures including a Blalock operation, resection of an abdominal aneurysm, and three craniotomies for cerebral aneurysm in which it was combined with hypothermia.

Anesthetic Technique. Premedication was not standardized. Of the 300 patients, 220 received atropine; 78, scopolamine; and 2 received neither. A narcotic, morphine or meperidine, was used in the premedication of all except 13 patients.

Induction of anesthesia usually was accomplished with a dose of thiopental rarely exceeding 250 mg. The patient then respired through a rebreathing circuit to which 250–500 ml./minute oxygen flows were added. Technical difficulties sometimes made it impossible to proceed with strictly basal oxygen flow rates, but we have included flow rates of up to 500 ml./minute in the closed circuit series. Succinylcholine in doses of 40–80 mg. was usually employed to facilitate tracheal intubation in the 150 cases where endotracheal anesthesia was used.

Halothane was introduced sometimes before, usually after, tracheal intubation. The initial increment was 0.4 ml. followed in approximately one minute by a second 0.4 ml. From this point increments of 0.2 ml. were added as necessary to obtain the desired de-

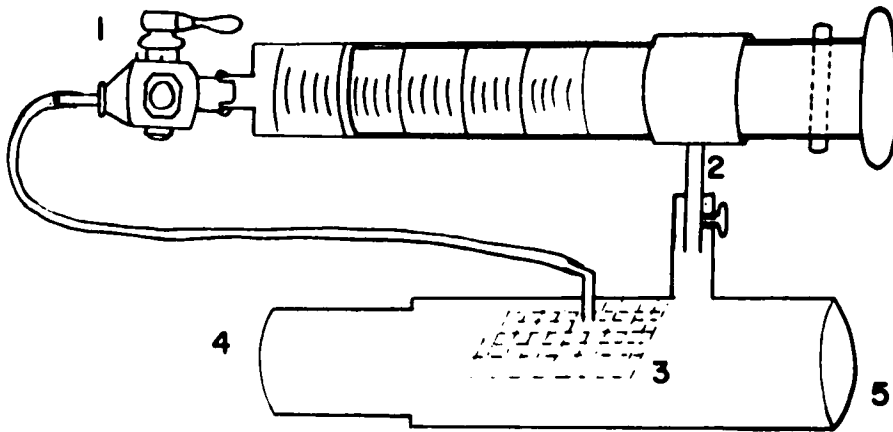


FIG. 1. Vaporizing device for halothane. The screen within the exhalation pathway may be of copper or stainless steel. (1) 3-way stopcock, (2) swivel, or adjustable holder for 5 or 10-ml. syringe, (3) copper screen, (4) connection for exhalation tubing, and (5) connection to carbon dioxide absorber.

gree of central nervous system depression. Anesthesia was maintained by using 0.2 ml. of halothane approximately every three to five minutes. These were average doses for adults. Relaxants, chiefly gallamine or succinylcholine, were used when considered indicated; in this series in 123 patients. Respiration was manually controlled in 155 cases whenever it was considered to be useful or necessary.

Analysis of Inspired Halothane Concentrations. Concentration of halothane in inspired gas was measured in 12 patients. We used a catharometer designed to measure thermal conductivity of halothane in oxygen. This was calibrated against each of two Fluotec vaporizers and gave linear results in the range of one to three per cent when a flow rate of 4 l./minute was used. In one Fluotec the 0.5

per cent setting produced a smaller galvanometer deflection than predicted from the line obtained at higher scale settings. This was assumed to be an error in the vaporizer.

When measurements were to be made the patient breathed oxygen for a minimum of seven minutes before induction of anesthesia to obtain nitrogen washout. Sampling was done continuously or intermittently from the inhaler tubing adjacent to the inspiratory directional valve, which was at the mask or endotracheal tube connection.

RESULTS

The various clinical actions, favorable and otherwise, usually attributed to halothane were observed in this study. Two effects deserve emphasis because they were brought into sharper focus no doubt since halothane was the sole anesthetic agent used (excluding the minimal doses of thiopental), in contrast to studies in which it was combined with nitrous oxide or other agents.

Analgesia. The agent lacks good analgesic properties in the first twenty minutes of administration. Furthermore, depth of anesthesia is difficult to define clinically particularly if relaxants are used or ventilation is controlled. Many patients who appeared to be in a surgical plane of anesthesia moved when the incision was made. Attempts to obviate this by deepening the anesthesia frequently re-

TABLE 1

Types of Operative Procedures	Number
Neurosurgical, intradural (aneurysm)	3
Neurosurgical, extradural	9
Head, neck	10
Tonsillectomy and adenoidectomy	10
Intrathoracic	14
Extrathoracic	22
Abdomen, general	61
Genitourinary, major	9
Gynecological, major	59
Genitourinary and gynecological, minor	81
Extremities	22
Total	300

sulted in hypotension. Inclusion of a narcotic in the premedication seemed helpful in preventing these embarrassing situations. Administration of a small dose of alphaprodine (Nisentil) immediately prior to induction of anesthesia, in the few instances where it was done, provided sufficient added analgesia for the commencement of the surgical procedure.

Hypotension. This we defined as two or more systolic readings of less than 80 mm. of mercury read at intervals of two to five minutes. It occurred in 27 patients, and was so transient in 5 as to require no treatment.

The most frequent cause seemed to be too rapid presentation of agent, and return to more nearly physiologic levels occurred promptly after flushing the rebreathing bag with oxygen (fig. 2). If the hypotension was accompanied by bradycardia it seemed to respond to 0.4 mg. of atropine or 40 mg. of gallamine given intravenously. Visceral traction, particularly during biliary tract surgery, frequently was accompanied by hypotension. Blood loss accounted for four episodes of this complication.

In the immediate postanesthetic period in

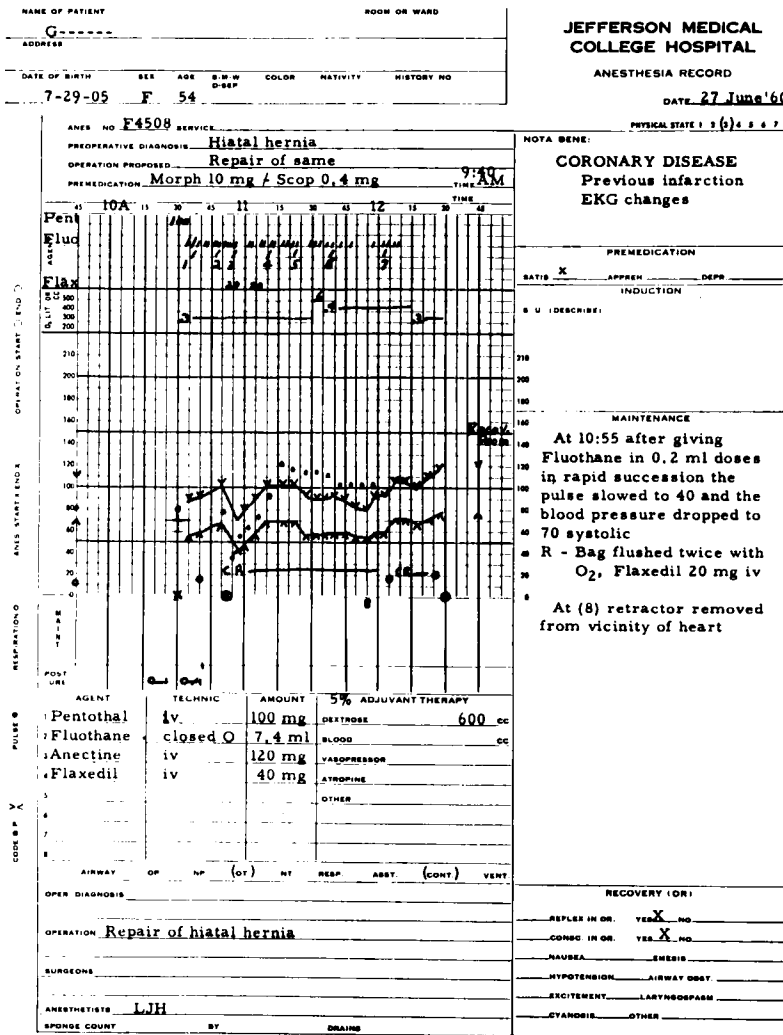


FIG. 2. Anesthesia record illustrating production of hypotension by overdose of halothane. Each short crosshatch represents 0.2 ml. of halothane.

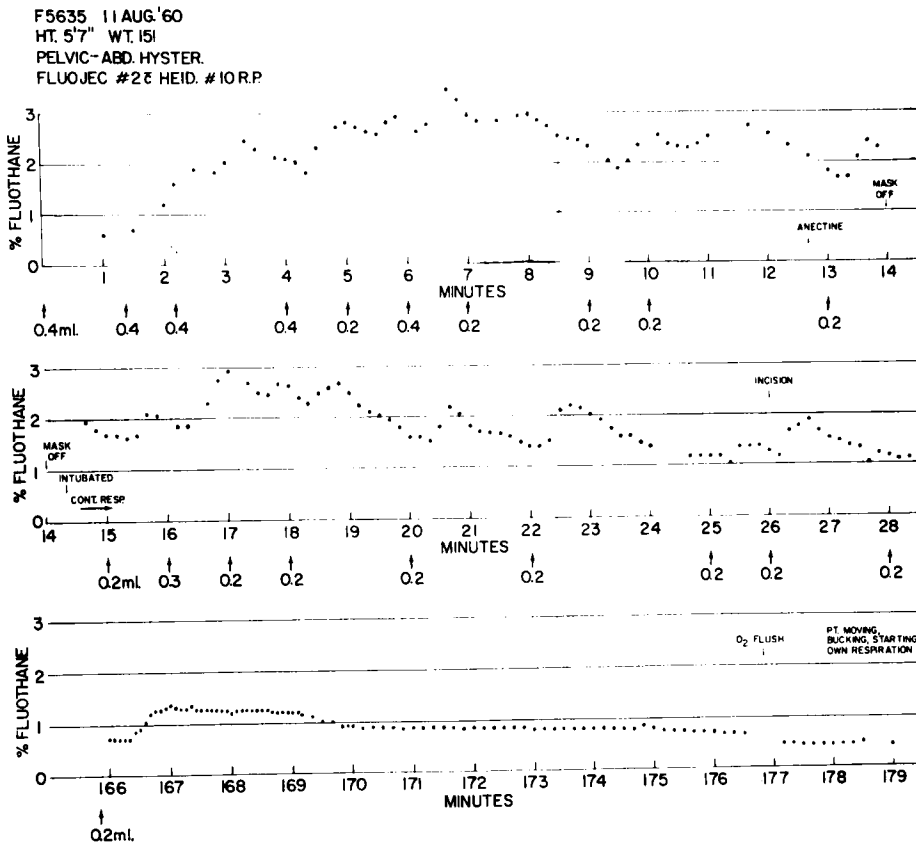


FIG. 3. Concentration of halothane in inspired gas with vaporizer in exhalation arm of breathing circuit.

the recovery room 13 patients were noted to have a systolic blood pressure below 80 mm. of mercury. Of these, three responded promptly to vasopressors, and three to Trendelenburg's position. The others gradually became normotensive spontaneously.

There were no deaths attributed to the agent or the method.

Measurement of inspired halothane concentrations made in twelve adult patients showed values during induction which ranged between 2 and 3 per cent (in one instance 3.4 per cent). Concentrations during maintenance ranged from 0.8 to 2.0 per cent, and usually were in excess of 1 per cent (figs. 3 and 4).

The rate of utilization of halothane decreased with increase in duration of the operative procedure (table 2). From the standpoint of economy the technique seemed most useful in procedures having a duration in excess of one hour. The costs of anesthetic materials, excluding carbon dioxide absorbent, used in 18 patients for cholecystectomy and 28 patients with abdominal hysterectomy were compared with the costs in a like number of similar procedures anesthetized with halothane-nitrous oxide in semiclosed technique. The results are shown in table 3.

TABLE 2
RATE OF UTILIZATION OF HALOTHANE

Duration of Operation (Hours)	Number of Cases	Average Amount Halothane per Hour per Case (ml.)
0- $\frac{1}{2}$	52	6.03
$\frac{1}{2}$ -1	43	5.64
1-2	89	4.24
2-3	73	3.84
3-4	26	3.15
4-5	10	2.46
5-6	7	2.48

DISCUSSION

The amount of halothane vapor produced by a known volume of liquid can be calculated from the formula

$$\frac{\text{ml. liquid} \times \text{sp. gr.} \times 22,400}{\text{mol. wt.}} = \text{ml. vapor.}$$

In usual operating conditions the addition of 0.4 ml. halothane liquid to the vaporizer produces approximately 84 ml. vapor. In induction of anesthesia when this volume is added to a gaseous system (absorber, rebreathing bag, inhaler tubing, lung volume) whose content may exceed 6,000 ml. one should expect an inspired concentration of less than 2 per cent. Addition of a second increment one minute later, even if no uptake had occurred in the meantime, should not push the concentration beyond 3 per cent.

Halothane is rapidly absorbed from the alveoli. Rate of body uptake does not fall as rapidly as is the case for many other agents,

TABLE 3

COSTS OF ANESTHETIC MATERIALS
(EXCLUDING CO₂ ABSORBENT)

Procedure	Technique	Costs/Hour
Cholecystectomy (18 cases)	Semiclosed*	\$2.79
Cholecystectomy (18 cases)	Closed circuit	1.13
Abdominal hysterectomy (28 cases)	Semiclosed*	2.20
Abdominal hysterectomy (28 cases)	Closed circuit	0.92

* Cost of nitrous oxide based on E cylinder price.

and is in the order of 10 to 15 ml. vapor per minute over the course of several hours. The rate does fall in time, but for the duration of the average surgical procedures the above figures may be sufficiently accurate. Addition of increments of 0.2 ml. liquid (42 ml. vapor) every three minutes should approximately balance the uptake, and the inspired

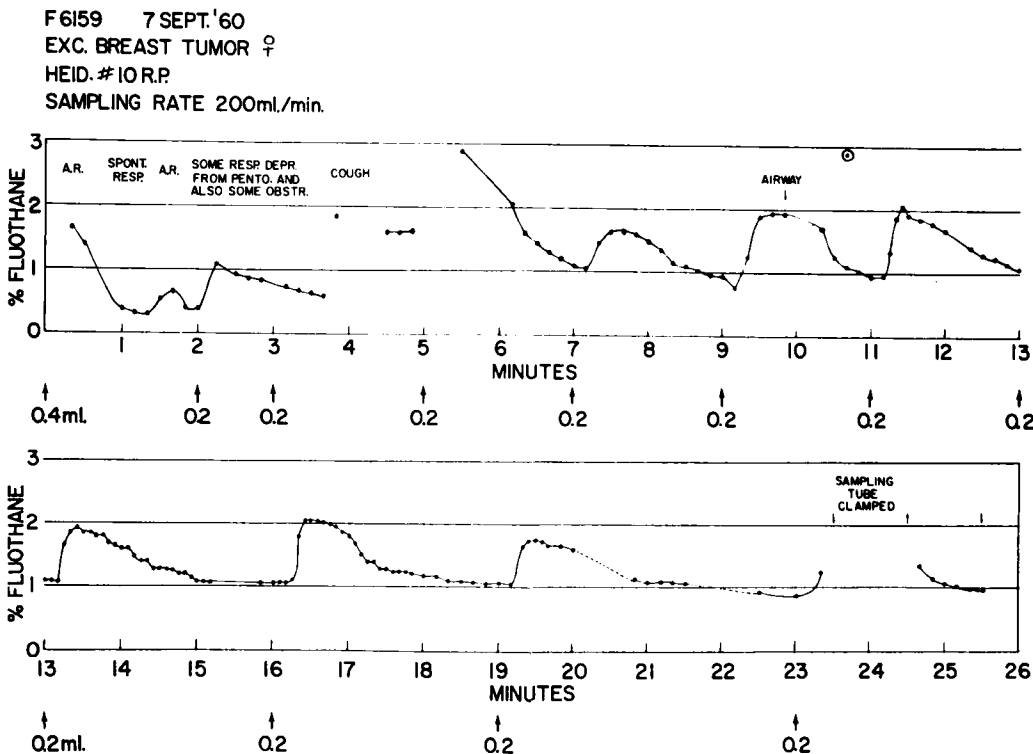


FIG. 4. Concentration of halothane in inspired gas with vaporizer in inspiratory arm of breathing circuit. Note the cough during induction and rapid rise in concentration of halothane with deep inspiration following cough.

concentration should not be expected to exceed the accepted safe limits of 2.5 per cent⁵ during maintenance. Measurements which were made in 12 patients confirmed these assumptions.

Controlled ventilation and positioning of the vaporizer in the gas inlet or expiratory pathway of the circuit should be safe if suitably small increments are added at sufficiently long intervals. Hypotension occurs when the agent is "pushed" too rapidly, and is the one clinical sign which is of most value in determining the length of interval to be used between doses. The method has the additional safety factor that deepening of anesthesia requires the activity of the anesthetist. Inattention from any cause results in lengthening of interval between doses and, hence, lightening of anesthesia.

Lack of analgesia in the early part of the procedure was at times annoying. In this respect in the first twenty minutes the agent behaves like thiopental in that it seems to provide amnesia, but inadequate analgesia. For this reason we advocate the use of a narcotic in the premedication or intravenously immediately prior to induction.

While the total amount of halothane used for a given procedure by this method will probably be less than would be the case with a semiclosed or nonrebreathing method, the amount taken up by the body may be more. Patients anesthetized by this technique may sleep longer postoperatively. We have found that flushing the rebreathing bag repeatedly with oxygen near the end of the procedure will usually result in a prompt return of reflexes and an ability to respond to simple commands. Return of full consciousness may,

however, be slower than one would expect with a nonrebreathing technique.

SUMMARY

Halothane has been administered in a closed circuit using a vaporizer which can readily be placed in the gas inlet or exhalation side of the circuit. The liquid agent is added from a syringe in known increments at intervals suitable for the production of anesthesia. The output of the vaporizer is not influenced by volume of ventilation and thus controlled ventilation may be used when indicated.

Inspired concentrations of vapor admittedly must be calculated and are not known without use of an analyzer. Total amounts of agent used are always known. Safety of administration remains, as with other methods, dependent upon clinical observation of the patient.

The method is economical.

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