FURTHER EXPERIENCES WITH ENDOTRACHEAL ETHER-AIR ANESTHESIA FOR INTRATHORACIC SURGERY * †

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INTRODUCTION

A METHOD has been introduced for the control of ventilation and anesthesia in intrathoracic surgery using a mixture of ether and air not enriched with oxygen (1). The original intention was to provide a means whereby anesthesia and ventilation could be maintained with very simple apparatus while the chest was held open for long periods of time. The emergency nature of the original demand suggested that even oxygen might not be available under some circumstances. The animal and subsequent clinical studies were therefore an attempt to find a substitute for the intermittent, rhythmic control of ventilation afforded by the "to-and-fro" carbon dioxide absorption technic with oxygen and cyclopropane or ether. It was generally agreed that, while the method should provide good anesthesia with a minimum of equipment, it should not be expected to substitute for training or experience on the part of the physician who uses it.

Because of our initial success with the method, we have been encouraged to give it a more extended trial. During the past sixteen months we have used ether-air anesthesia with the Stanford vaporizer, valve, and bellows on most intrathoracic operations, including lobectomies, pneumonectomies, transthoracic gastric and esophageal resections, and exploratory thoracotomies. During this time we have used this method in 50 cases with no selection as to the risks. The results appear sufficiently satisfactory to warrant a further, more detailed account of the procedure and to suggest it as a method of choice for ventilation and anesthesia for intrathoracic operations.

PREMEDICATION

Morphine sulfate and scopolamine in the ratio of 25:1 are given one and one-half hours before operation. Ordinarily the average adult is given morphine, grain 1/6 (0.01 Gm.), and scopolamine, grain 1/150 (0.0004 Gm.); only those who are very large and vigorous are given morphine, grain 1/4 (0.015 Gm.), and scopolamine, grain 1/100 (0.0006

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Gm.). During the early part of the study nearly all the patients were given the larger dose, but this caused a fair percentage of the patients to be so depressed as to render the induction of anesthesia slow and somewhat difficult.

For children under the age of 12 years, the dose of premedicants is reduced by taking into account their age and weight.

Induction of Anesthesia

For the most part anesthesia has been induced with nitrous oxide, oxygen, and ether with complete rebreathing without soda lime. This facilitates rapid induction by building up carbon dioxide, thus stimulating the respiration.

When the anesthesia has progressed to deep second or third plane, an oro-endotracheal tube is passed under direct vision and is connected directly to the Stanford vaporizer. The largest possible endotracheal catheter is used (38 or 40 French for women, 40 to 44 French for men). All tubes smaller than 44 French have an inflatable cuff to assure an air tight fit.

During the induction period there is often a marked rise in blood pressure as a result of the increased carbon dioxide level in the blood stream. The blood pressure falls to the preanesthetic level or slightly below it after intubation has been performed and the excess carbon dioxide has been blown off.

Pentothal was used in 6 cases in amounts ranging from 0.6 Gm. to 1.0 Gm. given as a single rapid injection after which intubation was performed and manual respiration carried out. However it was found that with the larger doses recovery of reflexes was delayed in cases in which an unexpected extension of a malignant lesion rendered it unresectable and thereby greatly shortened the operative period. When the dose was too small, severe laryngospasm occurred as intubation was attempted. Moreover, a marked drop in blood pressure level occurred with the injection of the pentothal, but this returned to its previous level very quickly when small doses of neosynephrin (½–1½ mg.) were injected intravenously. Incorporating 1–2 mg. of neosynephrin into the 40 cc. of 2.5 per cent pentothal solution prevented the decrease.

Controlling the Respiration

When the thorax is open it is necessary to ventilate the lungs by rhythmically and intermittently inflating them with the valve and bellows. This can be most efficiently carried out if the patient makes no respiratory movements of his own. The absence of respiratory movements is also a distinct aid to the surgeon. Ordinarily the complete control of respiration can be secured very quickly by inflating the patient's lungs 15 to 20 times per minute at pressure of 10 mm. of mercury, being careful to make the expiratory phase twice as long as the inspiratory phase. If ample time is not allowed during expiration for the lung to collapse completely, the desired low level of carbon dioxide will not be reached, and diaphragmatic movements will continue.

At times the depression obtained from such small doses of morphine as are given for premedication is inadequate for easy control of respiration, and added depression is obtained by giving morphine intravenously as needed during the early course of the anesthesia. Grain ⅛ (0.008 Gm.) given once or twice is usually sufficient; scopolamine is omitted since respiratory depression is the sole object. Intravenous administration has the advantage of quicker and shorter action over hypodermic injection.

After all respiratory movements have ceased, inflation of the lungs ten to twelve times per minute with good amplitude will usually maintain this state.

CASES NOT REQUIRING POSITIVE PRESSURE

There are some instances in which positive pressure is not necessary during intrathoracic surgery. Most frequent among these are those cases in which previous operation and/or empyema has resulted in a thickened, immobile mediastinum. The fixed mediastinum prevents paradoxical respiration, and the intact side functions normally in spite of a wide open pneumothorax on the opposite side. Moreover, in such cases the affected lung is quite often only a dense mass of necrotic, functionless tissue, and inflation of it is neither plausible nor profitable. Pericardiectomies in which the approach is made directly into the anterior mediastinum require no positive pressure unless the pleural cavity is opened. Some paradoxical respiration will be noted, but this is usually not sufficient to cause any respiratory embarrassment. Positive pressure is ordinarily not required for any operation on the mediastinum during which the integrity of the respiratory system is maintained.

When positive pressure is not required, an improvised exhalation valve is inserted between the endotracheal tube and the vaporizer in order to reduce the dead space in the apparatus to a minimum (figs. 1 and 2).

MAINTENANCE OF ANESTHESIA

The depth of anesthesia must be watched closely. If the anesthesia becomes too light, the respirations are difficult to control because the patient tries to extrude the tube by straining, and under these conditions it is difficult for the surgeon to work. If anesthesia becomes too deep, the patient soon begins to sweat and show signs of approaching shock, and it must be remembered that except for thoracotomies these operations take upwards of three hours.

Usually midsecond plane anesthesia is satisfactory, but the difficulty comes in judging the depth when the respiratory signs, the most valuable signs of anesthesia, are not available. We regulate the depth of anesthesia partly by observation of the patient's pupil size, but mostly by closely watching his general condition.

Traction on the hilar structures causes the patient to strain and cough, making it almost impossible to ventilate the lungs. Along with the respiratory reactions, severe cardiovascular reflexes are often

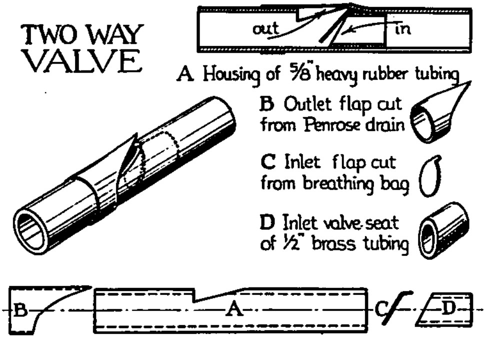

Fig. 1. Exhalation valve dissembled to show component parts and assembled ready for use.

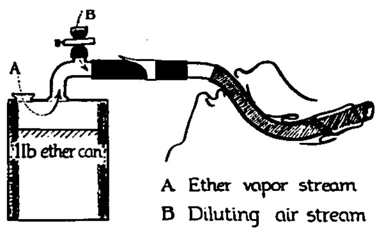

Fig. 2. Vaporizer, exhalation valve, and endotracheal tube connected together as they are when in use.

elicited. They are typically characterized by a declining blood pressure level and a slow pulse. The control of these reflexes by general anesthesia alone is very difficult and profound anesthesia is required. We make a practice, therefore, of having the surgeon infiltrate the hilar structures with 0.5 to 1 per cent procaine, which is reasonably successful in alleviating the condition.

Mechanical Interference with Ventilation

The pressure of retractors or packs on a lung with intact blood supply will interfere with the normal gaseous exchange. Since half the blood reaching the lungs goes to the nonaerated pulmonary tissue there will be a resultant hypoxemia and hypercarboxemia. Moderate degrees of compression do not produce this effect.

A retractor which partially occludes a bronchus produces a ball-valve action, causing the section of lung associated with this bronchus to be gradually blown up like a balloon. Not only will there be resultant failure of carbon dioxide clearance and subsequent respiratory movements, but also the surgeon will be certain to complain that the lungs are being ventilated too vigorously while the contrary may be true.

ENDING THE ANESTHESIA

As soon as the specimen has been removed or approximately forty-five minutes before the end of the operation, the ether vaporizer is disconnected and anesthesia is lightened. This is possible because no relaxation is necessary for the closure of the thorax, and the endotracheal tube is usually tolerated under very light anesthesia at this point.

When the thorax is air tight, the pneumothorax is obliterated by expanding the remaining lung tissue while allowing the entrapped air to escape via a needle, catheter, or hemostat inserted into the pleural cavity. This, of course, is not done after pneumonectomy.

Reestablishing spontaneous respiration is usually a very simple matter under the lightened anesthesia, since at this time it is often difficult to retain complete control. Usually it can be accomplished by inflating the patient's lungs and allowing the weight of the bellows to keep the exhalation valve closed. In a very short time spontaneous respiratory movements begin. They are at first jerky diaphragmatic movements uncoordinated to intercostal movements, but soon they take on the nature of normal respiration. Occasionally, because of the development of cyanosis before the onset of spontaneous respiration, ventilation must again be carried out, and the procedure described is repeated.

Before removing the endotracheal tube careful tracheobronchial toilet is performed during which the patient usually coughs violently, the coughing being as desirable as the suction for the recovery of secretions. The upper passages are cleaned by thoroughly removing all the secretions from the nose and mouth. A 14 or 16 French catheter is ideal for this procedure.

The endotracheal tube is then removed, and a pharyngeal airway is inserted if necessary. Usually, however, by this time the patient is nearly awake. In fact it is usual to have the patient awaken in surgery as the skin closure is being finished. Because of the analgesic power of ether this is tolerated even though the patient is awake. Nausea and emesis are usually not evident at this time.

SUPPORTIVE TREATMENT

Since these operations take upwards of three hours, usually with appreciable blood loss, it is important to start administration of fluids early, preferably before the operation begins. During the average case patients receive 1,000 cc. of blood and 500 to 1,000 cc. of physiologic saline solution.

If the operation is made unduly difficult by adhesions, the bleeding is often very profuse, and further parenteral therapy is necessary. Blood is the fluid of choice, but it is often necessary to use plasma until the blood arrives. In cases of very severe hemorrhage it is not uncommon for two intravenous sets to be running simultaneously.

During one case in which the anesthesia was maintained five hours and twenty-five minutes, a large rent was opened in the inferior vena cava with resultant sudden severe hemorrhage and shock. Two liters of blood, 250 cc. of plasma, and a liter of saline solution were given. The blood pressure and pulse were imperceptible for about one hour, but they were 120 mm. systolic and 90 mm. diastolic and 110, respectively, immediately after the operation ended.

With very severe hemorrhage the blood pressure level and pulse rate often cannot be maintained by replacement therapy alone. In these cases neosynephrin is used to help maintain the cardiovascular system. It is usually given by adding it to the intravenous solutions. The usual dose is about 2½ mg. in 200 cc. of solution. Unless the patient is in profound shock, the usual response is an increase in blood pressure and a slowing of the pulse. If the blood containing the neosynephrin is given at the rate deemed necessary to combat the blood loss, sometimes the response to the drug is too great, resulting in a greatly increased blood pressure. This can be guarded against by having two separate intravenous solutions running, one of which does not contain neosynephrin, or by having a simple, open top reservoir for the intravenous set so that the neosynephrin can be added to or omitted from small amounts of solution as indicated. The open top reservoir permits the neosynephrin solution to be emptied into a sterile container and replaced by untreated blood.

Often after the blood pressure level has been brought up to normal with neosynephrin, blood alone will maintain it. The action of the drug lasts for about ten to fifteen minutes after cessation of its administration, and if the blood pressure stays up after this time, one can feel reasonably certain that it is not due to the drug, but to the improved condition of the patient.

Besides replacement and drug therapy, the anesthesia is lightened as much as is feasible, thus removing ether as a shock-producing factor. It must be remembered that the amount of ether required to keep a patient in severe shock at a given depth of anesthesia is much less than that required for a robust one.

OXYGEN THERAPY

After all operations for lobectomy or pneumonectomy, oxygen is started in the operating room by means of an oropharyngeal catheter and given continuously thereafter at about 8 liters per minute. Administration for twenty-four to forty-eight hours usually suffices for patients who have had lobectomies, but after pneumonectomies a longer time is required. It is preferable to reduce the oxygen gradually and watch the patient's pulse, respiration, and color for adverse reactions rather than to use arbitrary time limits. After other open thoracic operations, oxygen is given only as treatment for postoperative shock.

An 8 or 10 French catheter with 8 to 12 small holes in the terminal ½ inch serves well as an oropharyngeal catheter. In the unconscious patient a length equal to the distance from the ala of the nose to the anterior portion of the ear places the tip in the nasopharynx. In the conscious patient the catheter tip should be inserted just short of the place where he can swallow a bolus of oxygen. It should be removed and cleaned at least every twenty-four hours and replaced in the other nostril.

When these cases are placed under the care of those not accustomed to handling them, all too often the oxygen will be discontinued for varying lengths of time because of some minor derangement of the apparatus. Because of the decreased ventilating space of these patients they are often found to be anxious and restless and have a rapid pulse, all of which are usually relieved by starting the oxygen again. Just a short period of oxygen want may be the cause of death in a critical case.

CYANOSIS

With ether-air anesthesia cyanosis sets in rapidly when any factor exists that interferes with proper aeration of the lungs or oxygenation of the blood. The extreme sensitivity of the patient's color reaction to only minor disturbances of the respiratory system often calls the anesthetist's attention to small collections of secretions that might have been overlooked with anesthesia making use of oxygen excess. Removal of the secretions in these cases produces immediate return of normal color.

Too light anesthesia with straining and consequent poor ventilation also rapidly produces cyanosis. Correction of the condition rapidly improves the patient's color.

Sudden cardiovascular collapse from massive hemorrhage or severe surgical shock from other causes with stagnation of the blood flow also produces cyanosis. In these cases it has been found that the administration of oxygen in high concentrations does little if anything to improve the color and clinical state of the patients. Parenteral therapy and neosynephrin in amounts necessary to improve the cardiovascular state bring rapid improvement in the color, and in our experience have proved to be the best method of treating this condition.

ACCIDENTS

Certain accidents have occurred to the patients included in the data of this paper. It is fitting that these accidents should be mentioned to prevent their recurrence.

After one successful transthoracic resection of the esophagus oxygen was connected to a Levine tube leading into the stomach with the mistaken belief that it was a nasal catheter. The oxygen was then administered at 8 to 10 liters per minute, and this resulted in rapid exodus.

Oxygen was being administered postoperatively to a patient who had had pneumonectomy, with apparatus consisting of a flow meter and humidifier without a safety trap. The large tank became empty, and the flow meter and humidifier were transferred to a full tank without turning off the valve on the flow meter. When the valve on the high pressure tank was opened, the sudden blast of oxygen carried considerable water across into the patient's pharynx and lung, nearly drowning him. However, luckily he coughed up most of the water and his lung was able to absorb the rest, averting a catastrophe.

Following one pneumonectomy during which heroic measures were required to combat the hemorrhage produced by opening the vena cava, a catheter leading to the pleural cavity was hooked up to continuous Wangensteen suction. In spite of the fact that the patient was in fair condition on reaching his room, with blood pressure of 120 mm. systolic and 80 mm. diastolic and pulse of about 100, he died fifteen to twenty minutes later. Necropsy failed to show any cause of death, and so it was assumed that the suction produced mediastinal shift, with consequent failure of a severely strained cardiovascular system.

Aspiration of vomitus, which is a danger after any operation, occurred once in our series. It was not reported to the surgeon and went untreated. Pneumonitis and death followed.

On the first postoperative day following pneumonectomy the patient was given 1 liter of saline too rapidly, the whole volume being given in twenty minutes. This sudden overloading of the circulation with fluid caused pulmonary edema and death.

CLINICAL SURVEY

In our series of 50 cases all age groups have been represented. As might be expected, the first two decades of life were the most poorly represented, there being only one case for the first and two for the second. The youngest patient was 8 months and the oldest 75 years. The shortest operation was fifty minutes, and the longest was seven hours and fifty minutes.

A list of all our cases along with their ages, operation, duration of anesthesia, and some statement about their postoperative courses is given in table 1. No attempt has been made to analyze the data.

TABLE 1

Complete List of Cases

Case	Age, years	Operation	Duration*	Postoperative Course
1 JP	55	Right pneumonectomy	3:25	Uncomplicated.
2 GM	63	Left pneumonectomy	4:20	Uncomplicated.
3 FY	63	Exploratory thoracotomy	1:30	Uncomplicated.
4 FT	72	Transthoracic resection of the esophagus	4:55	Uncomplicated for 11 days. Then a fistula developed from the esophagus into lung and later patient died from extensive pneumonia.
5 RH	44	Right pneumonectomy	5:35	Recovered well from the effects of severe hemorrhage. Condition remained good until a catheter leading to the chest cavity was connected to continuous suction whereupon the pulse suddenly stopped and death ensued. Necropsy revealed no cause of death. Believed due to mediastinal shift.
6 VB	43	Exploratory thoracotomy	1:50	Long febrile course due to tumor. Home 39 p.o. day.
7 GC	45	Exploratory thoracotomy	2:10	Uncomplicated.
8 JG	71	Exploratory thoracotomy	1:20	Uncomplicated.
9 EC	65	Left lower lobectomy	3:15	Uncomplicated.
10 FK	48	Repair of right lung for tension pneumothorax	1:15	Developed mediastinal emphysema and died 2nd p.o. day.
11 JC	67	Exploratory thoracotomy	1:00	Febrile from tumor to 16th day. Returned home well.
12 MM	39	Lung suture for tension pneumothorax	1:50	Uncomplicated.
13 LL	62	Transthoracic resection of esophagus, upper end	4:50	Returned from surgery in good condition. Incision became a sucking wound of the chest, and he became dyspneic and died on 1st p.o. day.
14 BD	8 mo.	Transthoracic repair of diaphragmatic hernia	2:10	Uncomplicated except for p.o. feeding difficulties and bleeding into the bowel requiring long hospital stay.
15 LC	35	Left lower lobectomy	3:15	Uncomplicated.
16 JR	59	Right lower lobectomy	3:10	Apparently uncomplicated until the 18th p.o. day when he died from a pulmonary thrombosis.

* "Duration" refers to the length of time in hours and minutes that the patient was under anesthesia.

TABLE 1—(*Continued*)

Case	Age, years	Operation	Duration*	Postoperative Course
17 FR	62	Thoracotomy	1:25	Uncomplicated.
18 BP	29	Right lower and middle lobectomy	3:32	Uncomplicated.
19 MS	24	Left lower lobectomy	4:05	Uncomplicated.
20 EJ	27	Right lower lobectomy	4:25	Uncomplicated.
21 WW	43	Left lower lobectomy	4:20	Uncomplicated.
22 WL	44	Right pneumonectomy	3:00	Ran low grade fever 9th to 24th p.o. days apparently due to the absorption of blood in the pleural cavity. Otherwise uncomplicated.
23 MC	52	Exploratory thoracotomy	2:00	Uncomplicated.
24 EL	23	Incision and drainage of lung abscess	0:50	Uncomplicated.
25 FD	75	Transthoracic resection of esophagus	4:00	Left surgery in good condition, but died on the first p.o. day.
26 JC	43	Transthoracic gastric resection	4:05	Uncomplicated.
27 EQ	50	Pneumonectomy	5:00	In good condition after surgery and following a.m. Then died of pulmonary edema after very rapidly receiving 1000 cc. of saline intravenously.
28 JE	27	Pneumonectomy	3:30	Uncomplicated.
29 PS	54	Exploratory thoracotomy	2:00	Uncomplicated.
30 AG	48	Right lower lobectomy	5:15	Bronchial stump blew out and fever developed on 7th p.o. day. Empyema developed, treated by Eloesser flap. Discharged on about 70th day.
31 AG	49	Completion of right pneumonectomy (same patient as Case 30)	3:55	Early course uncomplicated. Died 12th p.o. day from hemorrhage.
32 MS	27	Left lower lobectomy	7:50	Aspirated vomitus. Not reported to surgeon. Seemed all right for 4 days. Then pneumonitis and empyema developed and patient died.
33 TR	47	Decortication of lung	2:05	Uncomplicated.
34 WM	51	Exploratory thoracotomy	2:10	Uncomplicated.

TABLE 1—(*Continued*)

Case	Age, years	Operation	Duration*	Postoperative Course
35 AP	65	1st stage pneumonectomy, right	4:45	Uncomplicated.
36 AP	65	2nd stage pneumonectomy, right	3:45	Uncomplicated.
		(Each stage stopped because auricular fibrillation developed. Operation was later completed at third stage using carbon dioxide absorption technic without positive pressure.)		
37 JR	47	Right pneumonectomy	3:30	Uncomplicated.
38 HJ	?	Left upper lobectomy	3:05	Died on the 14th p.o. day from hemorrhage. Previous course uncomplicated.
39 WK	22	Left lower lobectomy	4:05	Uncomplicated.
40 EG	64	Right pneumonectomy	4:00	Uncomplicated.
41 LS	22	Pericardiectomy for constrictive pericarditis	3:15	Uncomplicated.
42 HA	69	Transthoracic resection of esophagus	2:33	Uncomplicated.
43 RG	38	Partial left upper and partial left lower lobectomy	2:50	Uncomplicated for first 10 p.o. days. Then bronchopleural fistulas, empyema, and diffuse bilateral bronchopneumonia developed leading to his death.
44 JR	15	Right middle and partial upper lobectomy	2:45	Course uncomplicated except for unexplained fever and hydrothorax. Sputum was later found to contain tubercle bacilli.
45 WM	62	Exploratory thoracotomy	2:00	Uncomplicated.
46 TC	63	Pneumonectomy	4:20	Hemorrhaged following surgery. Given 3 transfusions following which he became anuric, uremic, and died on the 3rd p.o. day. Thought to have had a transfusion reaction.
47 GM	44	Exploratory thoracotomy	1:25	Uncomplicated.
48 ED	14	Right middle and lower lobectomy, also partial upper lobectomy	3:50	Temperature returned to normal on 3rd p.o. day. Doing well for the rest of the first week p.o. in spite of fact that remaining portion of the right upper lobe had not fully expanded. Further follow-up not yet available.

TABLE 1—(*Continued*)

Case	Age, years	Operation	Duration*	Postoperative Course
49 HF	43	Transthoracic resection of the esophagus	5:50	In very good condition at end of operative procedure. Doing well 4 days p.o. Further follow-up not yet available.
50 JH	52	Exploratory thoracotomy	2:00	In good condition at end of operative procedure. All right on 1st p.o. day. Further follow-up not yet available.

SUMMARY

A detailed account of the method of using ether-air anesthesia with simple, improvised apparatus for intrathoracic operations has been presented. The method was originally developed to provide anesthesia and ventilation for intrathoracic operations performed under emergency conditions. It is now being presented as a possible method of choice for these operations even though more elaborate equipment is available. Certain accidents which occurred after anesthesia have been described.

REFERENCE

1. Neff, William, and Lind, Samuel: Ether Anesthesia with Improvised Apparatus for Intrathoracic Operations Under Emergency Circumstances, Anesthesiology 6: 337–348 (July) 1945.

MEETING OF THE AMERICAN SOCIETY OF ANESTHESIOLOGISTS, INC.

NEW YORK ACADEMY OF MEDICINE

2 East 103rd Street, New York, N. Y.

Thursday, February 14, 1946

Business Session: 8:15 P.M.

Scientific Session: 8:30 P.M.

"Some Problems of Men Wounded in Battle"—40 minutes.
By Henry K. Beecher, M.D., Massachusetts General Hospital, Boston, Mass.

"Death from Fat Embolism—A Case Report"—20 minutes.
By E. A. Doud, M.D., Doctors Hospital, New York, N. Y.

"Respiratory and Vascular Collapse in Epidural Block—A Case Report—20 minutes.
By Dante Bizzari, M.D., Metropolitan Hospital, New York, N. Y.

General Discussion.

Physicians and medical students invited.