

ANESTHETIC COMPLICATIONS AND THEIR MANAGEMENT *

MAJOR LLOYD H. MOUSEL †

Medical Corps, Army of the United States

DONALD STUBBS, M.D.,‡ AND JOSEPH KREISELMAN, M.D.§

Washington, D. C.

ANESTHETIC complications are essentially deviations from normal physiology. The *extent* of such deviation determines whether it results in a transient, abnormal state during anesthesia or in death on the operating table. The *duration* of upset physiology determines whether it leads to a postoperative complication or delayed death.

The transient complications of anesthesia are all due to anoxia under one or another of the complicated mechanisms which produce it. To justify this claim of close fundamental kinship among such entities as vomiting, pulmonary edema, shock, convulsions, and overdosage of anesthetic, it is necessary only to enumerate the various types of anoxia.

Adequate quantities of oxygen may fail to reach the blood under four conditions common in anesthetic practice:

(1) The respired atmosphere may contain inadequate amounts of oxygen due either to the failure to eliminate nitrogen from the gas anesthesia system or to the effort to use too high a concentration of anesthetic gas for its more rapid effect.

(2) Pulmonary ventilation may be deficient because of obstruction in the airway. Relaxation of soft tissues in the throat is the commonest cause of such obstruction but other serious causes are vomiting and laryngospasm.

(3) Pulmonary ventilation may be deficient as a result of central depression of respiration, caused most frequently by overdosage of anesthetic agent.

(4) There may be interference with the function of the alveolar membrane as from edema which is commonly present in some degree when there is anoxic increase in capillary permeability, obstruction to inspiration, or irritating fluctuations in ether concentration.

* Read before the meeting of The American Society of Anesthesiologists, New York City on April 12, 1945.

† Consultant in Anesthesia to The Surgeon General, U. S. A.

‡ Associate in Surgery, George Washington University, Washington, D. C.

§ Civilian Consultant in Anesthesia to The Surgeon General, U. S. A.

Adequate quantities of oxygen cannot be held in anemic blood even if none of the preceding conditions exist. Beyond this, however, normal quantities of normally oxygenated blood may fail to circulate adequately as in shock, and stagnant anoxia will exist. Also, histotoxic influences may prevent tissue oxygenation when everything else is normal. Finally, oxygen demand may be in excess of average requirement and routine handling will lead to a deficit. Anesthetic convulsions are the best clinical examples of this mechanism. Although they may not be initiated by anoxia alone, their great danger is due to it.

It is not too much to say that very few anesthetics progress for more than a few minutes in average hands without some degree of anoxia under some of the aforementioned headings. The danger which these patients narrowly avoid, and which frequently they fail to escape, is emphasized by such facts as the following, which are well known:

Complete cerebral anoxia for ten seconds produces unconsciousness; twenty to thirty seconds causes cessation of electroencephalographic brain waves; three to five minutes produces irreversible pathologic change in the cerebrum (1).

The myocardium tolerates anoxemia only so long as the coronary arteries can dilate enough for their extra circulation to compensate for it. In coronary insufficiency relatively mild degrees of anoxemia may cause heart failure.

Anoxia is the most dangerous depressant to the respiratory center and therefore tends to perpetuate and advance itself.

In shock, capillary permeability may be increased by anoxia to three or four times normal. This factor may produce an irreversible condition. It should be stressed that anoxia is commonly attended by excesses of carbon dioxide which add to the damage caused.

The anesthetist, then, who gives his patient less than 20 per cent oxygen, allows him to be hypoventilated because of a poor airway or central depression, fails to compensate for a damaged alveolar membrane or anemia, or allows shock to develop for any reason, is already dealing with a complication. Only early recognition and correction of the condition will keep it in the highly populated but relatively simple realm of transient complications of anesthesia.

While anesthetic complications are the result essentially of anoxia in their inception, they may branch out into definite directions if allowed to persist long enough to set the stage for postoperative continuity. They may then become rather definitely pulmonary, circulatory, metabolic, or cerebral complications.

The pulmonary complications which are directly related to anesthesia are primarily atelectatic in origin. Actual stoppage of air movement by mucous plugs in varying sizes of air passages causes greater or lesser areas of atelectasis. Decreased ventilation during and immediately after anesthesia aids this development. Failure to

recognize and treat it early promotes extension. Persistence for more than a few hours leads to infection in the collapsed area and this too may spread. This complication, in a minor degree, occurs frequently in average hands.

Because of a distant or indirect relationship to anesthesia, pulmonary infarction should be borne in mind as a postoperative complication. It is now becoming recognized that in any patient group at bed rest for more than a week, some degree of venous thrombosis is not uncommon, and that in a fairly high percentage of these cases minor pulmonary embolism may develop.

The early complications of circulation are shock-like in character and the originating effects of anesthesia and surgery can rarely be separated. More persistent defects may be related to anoxic damage to a previously diseased heart.

Even minor degrees of anoxia during anesthesia may aggravate liver damage, especially with certain agents such as vinethene or avertin. On the same basis, diabetic acidosis may be promoted.

The susceptibility of the cerebrum to anoxia accounts for the cases of temporary confusion and amnesia, more permanent ones of dementia even to the level of idiocy, and the acute, hyperpyrexia progress to a cerebral death in twenty-four to ninety-six hours after a period of anoxia.

Although nonfatal complications during and after anesthesia are relatively frequent, the drama and tragedy surrounding the fatal ones make them stand out as objects of study. Also in this group of cases, deviations from normal are greatest and mistakes in management are most glaring.

Nevertheless, death under anesthesia is much more frequent than is generally supposed. In nearly 50,000 anesthetics at Wisconsin General Hospital, Waters reported about 1 death per 1,000 cases (2). Gillespie, in nearly 250,000 cases, gave approximately the same incidence.

In studying 47 deaths under anesthesia in the Washington area, nearly all of them in the last two years in ten local institutions, we have found that the incidence varies from 1 in 300 cases to 1 in 8,000.

The report from the anesthetic service at Walter Reed General Hospital for 1944 indicated 1 death in the operating room in over 8,000 anesthetics. Since 1940 in Emergency Hospital, in over 22,000 cases there have been 3 deaths in the operating room. Of these 4 deaths, 2 were due to anesthesia. One was the case of a 200 pound, 39 year old woman given a spinal for pelvic laparotomy, with collapse during incision. The other was an infant in whom an endotracheal tube was used and was probably in one bronchus. Of the nonanesthetic deaths, one was a 65 year old woman who died of pulmonary embolism during manipulation of a hip five days after fracture. The other was at the end of a three hour exploratory operation of the fourth ventricle in a 14 year old boy who came to the operating room comatose, with Cheyne-

Stokes respiration, pulse of 140 and unobtainable blood pressure reading. For the last hour of the surgical procedure he was maintained by artificial respiration and blood transfusion. Thus, with only 4 deaths in the operating room on these two teaching services in 30,000 cases, we believe it is established that such an outcome should be much less frequent than is commonly found today.

The detailed study of any 47 deaths under anesthesia will yield important information. These cases are all from the civilian hospitals of Washington. The fact that most of them have deficient records is significant.

In the group under discussion, 5 deaths were largely surgical and anesthesia played no significant part. Two were from air embolism, 2 from pulmonary embolism, and 1 was the inoperable fourth ventricle tumor mentioned previously.

Three of the deaths were considered nonpreventable although anesthesia played some part. Of these, 1 was from hemorrhage and shock after four hours of resecting a rectum, 1 was in a moribund patient who had a thoracotomy, and 1 was from hemorrhage and shock after four hours of surgery for a cerebellar tumor.

In the other 39 cases death was considered to be preventable at least at the time it occurred, although 11 patients probably would have survived only a short time. These cases may be summarized as follows:

There were 9 children in the series. Of these, 4 had elective operations for hernia under ether, with death thirty to ninety minutes after beginning the operation; 1 death was from aspiration of vomitus during appendectomy; 1 from anesthetic shock during open reduction of a leg; 1 after ninety minutes of surgery in the fourth ventricle; and 2 deaths occurred during ethyl chloride induction before beginning surgery.

Eight adults in the series had laparotomy, including 1 cholecystectomy under ether and 1 under spinal; 1 pelvic laparotomy under gas-ether and 1 under spinal; 1 stab wound of the abdomen under pentothal-oxygen; 1 eight-day-old perforated ulcer under spinal, and in 1 case appendectomy was performed under gas-ether and the patient died following convulsions.

Five obstetrical cases were in the series. Three patients under ether and 1 patient under ethylene died following aspiration of vomitus. The fifth, under gas-ether, died following convulsions.

Of 5 patients who died following minor procedures, 1 was for incision and drainage under pentothal and 1 under ethylene-oxygen, 1 for anal dilatation under pentothal and another under pentothal for posterior colpotomy. The fifth patient had tonsillectomy under ether.

There were 4 cases of intestinal obstruction of which 3 patients received 20 mg. of pontocaine for spinal and 1 was given ethylene-ether.

There were 2 tooth extractions under nitrous oxide.

There were 2 thoracotomies under pentothal.

Among the miscellaneous cases were strangulated inguinal hernia in which ether was given to a 64 year old man, open reduction of a forearm under ethylene-ether, nephrolithotomy under ethylene-ether, and ligation of carotid under avertin-pentothal.

The following examples of faulty anesthetic selection were noted: pentothal-oxygen for closure after evisceration in a husky male, pentothal for stab wounds of neck and abdomen, avertin and pentothal for ligation of carotid in a 76 year old male with carcinoma of the antrum, ether for strangulated inguinal hernia in a 64 year old male, spinal for laparotomy in a patient with peritonitis of nine days' duration after perforated peptic ulcer, spinal for pelvic laparotomy in an obese, hyper-tensive, dyspneic female.

Among deficiencies of conduction, the failure to maintain an open airway with adequate oxygen was apparent in 20 cases. In 11 cases replacement therapy was inadequate to combat shock and hemorrhage. In 8 cases there was failure to guard properly against the aspiration of stomach content. In the two cases of convulsion there was the failure to lower oxygen requirement to the point where it could be met, and to reduce muscular spasm to permit ventilation by the intravenous use of barbiturates.

The most glaring deficiencies were in resuscitation. In 18 cases various drugs were injected directly into the heart, while some form of injection was used as a primary measure in 29 cases. Oxygen inflations were used early in only 10 cases, but in 12 cases manual artificial respiration was used.

Thus, in 33 of these 39 cases faulty resuscitative measures were used. In 24 cases, faulty management was an important factor leading to the final collapse. In only 8 cases was the selection of anesthesia considered to figure prominently in the outcome. We definitely concur with Ruth, in his excellent discussion of anesthetic study commissions, that inadequate resuscitation was the most frequent failure and that the next most common error was the tolerance of the anesthetist to anoxia in his patient. The severest criticism of Waters and Gillespie in their report on deaths in the operating room (2) is that they refer casually to "the usual resuscitative measures," "artificial ventilation by blowing air into the (tracheal) tube," etc., but nowhere describe what these usual measures are or should be. The contention that the method of artificial respiration is of little importance has done real harm. We are convinced that there are more wrong than right ways to resuscitate.

In the light of these findings, the place of cyclopropane in anesthesia should be reviewed. At Wisconsin General Hospital, where its use should be most skillful, the gross mortality from this drug was about equal to that from all other agents. Coupled with this is the fact that

about half of these cases showed primary, or at least very early, cardiac failure.

It is unlikely that any of these patients in whom cardiac failure was the initial form of collapse would have been saved by any perfection in resuscitative measures. On the other hand, it is practically certain that when respiratory failure existed, consistently good resuscitative measures would have saved many of the patients had other agents been used, thus making the differential mortality highly unfavorable to cyclopropane.

Since, as Courville (4) so rightly observed, anoxia is the greatest hazard during anesthesia, it follows that one of the essentials of a good anesthesiologist is good fundamental training to observe carefully, diagnose accurately, and treat adequately the clinical phases of this problem.

It is no fortuitous accident that in good teaching hands death from anesthesia and operation should occur in the operating room less than once in 7,000 cases, nor is it an unfair blow of fate that in the poorest type of anesthetic organization, typified by the hospital which uses only technicians responsible directly to the institution alone, death should come 20 to 25 times as frequently. In the long development of surgery, even the inferior fringes of this specialty have so nearly caught up with the leaders that their gross mortality is only 2 to 3 times as great. The fact that in the relatively young specialty of anesthesiology the ratio of worst to best is represented by the ratio of more than 20 illustrates how terribly wide is the gap between what is now being given on our best services and what is being suffered on the worst or even average ones. No one can argue that anesthesia, as practiced clinically, has a long way to go.

The management of anesthetic complications might be compared with the management of acute febrile conditions in children, such as epidemic diseases which are preventable. Diphtheria, typhoid fever, tetanus and other conditions may be prevented by proper prophylactic medicine. Likewise, most anesthetic complications can be prevented by using proper and intelligent preventative measures. Intelligent and judicious handling of the patient from the time he enters the hospital until he has recovered from his anesthetic will prevent most of the harmful sequelae to which many patients are subjected when handled in a routine and haphazard manner. Most anesthetic deaths are caused by the improper selection of anesthetic agents, improper administration, improper replacement therapy or failure to do efficient resuscitation. Many of the anesthetic deaths under general anesthesia occur during the administration of nitrous oxide or cyclopropane. Nitrous oxide is supposed to be one of the safest anesthetic agents available for use in producing anesthesia for relatively short operations. This gas has been used for almost one hundred years and with almost complete disregard for its dangers. The average anesthetist

administering nitrous oxide expects and observes some degree of cyanosis in his patients. Cyanosis is always an indication of reduced hemoglobin and anoxia. Most normal individuals tolerate a slight degree of anoxia for a short period of time without permanent damage to the higher structures. However, patients who are suffering from anemia, stagnant circulation or some other disease, may be in a state of chronic anoxia before the anesthetic agent is administered. An acute anoxia superimposed upon a state of chronic anoxia may cause the patient's death in less than one minute's time. It is the custom of many anesthetists to begin the induction of nitrous oxide anesthesia with a mixture of 90 per cent nitrous oxide and 10 per cent oxygen. If these gases are being administered at a barometric pressure of 760 mm. of mercury, the patient will be getting oxygen at approximately the pressure equivalent to that which he would be getting if he were breathing atmospheric air at an altitude of 18,000 feet. If a circle type filter were being used and the nitrogen had not been flushed from the machine, the patient would no longer be getting a mixture containing 90 per cent nitrous oxide and 10 per cent oxygen, but would be breathing a mixture diluted with approximately 45 per cent nitrogen. He would then be breathing an atmosphere containing oxygen at a partial pressure equivalent to that which he would be getting were he breathing air at an altitude of approximately 35,000 feet.

Many anesthetists speak with confidence about the basal oxygen needs. It is surprising to know that many of these individuals believe that a flow of 300 to 400 cc. of oxygen into the anesthetic bag will take care of the patient's oxygen requirements, disregarding completely the amount of anesthetic gas being delivered to the bag simultaneously. We have seen anesthetists inducing anesthesia with an oxygen flow of 300 cc. per minute and a nitrous oxide flow of 10 liters per minute. This represents a mixture of 97 per cent nitrous oxide and 3 per cent oxygen. At a sea level barometric pressure of 760 mm. of mercury, the patient will be getting oxygen at a partial pressure representing the oxygen in an atmosphere of 45,000 feet. Here again, if the nitrogen has not been removed from the system before the anesthetic agent is administered, the patient will be getting oxygen at a partial pressure representing that which would be found in air at an altitude above that which man has ascended. A method of nitrous oxide induction accomplished by the administration of pure nitrous oxide is to be severely condemned, for deaths or damage to the higher cerebral centers may result from this method (5). The method referred to as primary and secondary saturation (6) should never be practiced since the total deprivation of oxygen from many individuals may either prove immediately fatal or cause permanent damage to the higher brain centers. It is difficult to visualize any critical condition developing during the course of anesthesia which is not caused by, or closely associated with, oxygen lack. Sudden death on the operating table due to

cardiac failure such as is seen in cyclopropane (2) and chloroform anesthesia may be an exception. Almost all anesthetic deaths are the result of an acute anoxia and can be prevented provided intelligent and vigorous resuscitative measures are instituted at once. This means supplying oxygen to the tissues. It is imperative that positive pressure inflation of the lungs be instituted without delay and in such a manner as to insure the patient a sufficient tidal volume of oxygen to bring his oxyhemoglobin value to normal. Reliance upon suck and blow and the so-called analeptics or respiratory stimulants is a serious mistake. Coramine, metrazol, picrotoxin and alpha-lobeline should have no place in the armamentarium of the anesthetist (7). These drugs are not only of no value in resuscitation but may actually do a great deal of harm. In a patient with acute depression of the respiratory center, who is suffering from severe anoxia, the administration of analeptics tends to increase the depression (7). None of these drugs will stimulate respiration once a critical condition exists (8). It is true that some evidence of respiratory stimulant may be observed in lightly anesthetized laboratory animals as well as lightly anesthetized human beings. This respiratory stimulation is undoubtedly the result of increased metabolic demand and not of an effect of the drug upon the respiratory centers. Anesthetized animals show evidence of respiratory stimulation following the administration of the analeptics only in the preconvulsive state. It has been shown by Schmidt (10) and his coworkers that the analeptics actually increase the oxygen demand of the higher centers. If, during a state of acute depression, the patient is given coramine, metrazol, picrotoxin or alpha-lobeline, the state of anoxia is greatly increased. The end result of an increased tissue oxygen demand above the available supply is no different from further deprivation of oxygen from an already anoxic patient. Coramine is frequently recommended as being a cardiac stimulant. Those anesthetists who have used coramine for such a purpose should add a very small amount of this drug to the Ringer's solution of a perfused rabbit heart, and see what happens. Cardiac action stops almost immediately within the diastolic phase; administration of epinephrine is not likely to cause the heart to resume its normal activity.

It has previously been stated that acute emergencies arising on the operating table must be met by proper resuscitative measures, that is, resuscitation with oxygen. Many investigators and anesthetists recommend that carbon dioxide-oxygen mixtures be used for this purpose. Carbon dioxide has no place in the treatment of asphyxia. It is not only superfluous, it is actually harmful. There is no lack of carbon dioxide in states of asphyxia and acute anoxia (9). The blood carbon dioxide level is actually elevated. In states of acute depression with damage to the respiratory centers, carbon dioxide increases the depression. Experimental animals which have been asphyxiated may be given pure oxygen by positive pressure inflation for the purpose of

resuscitation. Once the respiration is resumed, the depth and rate of the respiratory excursions are usually normal. If these animals are resuscitated with a mixture of oxygen and carbon dioxide, the respiratory rate and depth will be very irregular until the administration of carbon dioxide has been discontinued (9). Resuscitation with adequate pulmonary ventilation may be accomplished by means of positive pressure inflation with oxygen, using the available anesthesia apparatus. The patency of the airway must be assured and sufficient pressure should be exerted on the anesthesia bag to inflate the patient's lungs. Usually the introduction of an endotracheal tube is not necessary. It is the custom of many anesthetists to delay inflation of the patient's lungs until an endotracheal airway has been passed. The time consumed in this maneuver might well be sufficient to cause the patient's death. Most patients' lungs can be inflated if a pharyngeal airway is properly placed and the jaw is supported in a forward position. Positive pressure of 10 mm. of mercury on the anesthetic bag is usually not sufficient to produce satisfactory inflation of the lungs. Pressures of 20 mm. of mercury are almost always required to inflate the lungs of an adult. This pressure may have to be exceeded in some instances. It will be noted that even 20 mm. of mercury positive pressure will not inflate the lungs of an individual whose respiratory efforts have been absent for more than a few minutes' time. The manual methods of artificial respiration are difficult and unsatisfactory. The tidal volume of air or oxygen required to maintain normal oxyhemoglobin saturation is known to be between 300 and 400 cc. Most manual methods of artificial respiration will not insure a tidal flow above 75 cc.

It is interesting to note how frequently manual methods of artificial respiration are carried out on the operating table, even though equipment for satisfactory ventilation with oxygen is immediately available. Manual artificial respiration is sometimes carried out by the surgeon simply by intermittent pressure on the patient's chest. Occasionally the patient may even be turned into a prone position so that the pressure can be exerted on the posterior aspect of the lower ribs.

In dealing with the management of anesthetic complications, a rigid regimen should be adopted. First of all, the anesthetic management must be in the hands of trained specialists. Groups of specialists working together as an organized team would be ideal, but at the present time such organizations are not possible except in a few of the teaching institutions of the country. Every hospital should at least have an anesthesia department which is under the control of a well trained and experienced anesthesiologist, the majority of the anesthetics to be administered by other trained men, residents or nurse anesthetists under constant, room to room supervision by the chief. Every department should be operated on a teaching basis. Nothing is so stimulating as the constant discussion within a teaching depart-

ment and nothing will improve the mind and judgment of the anesthesiologists as rapidly as the constant supervision and contact teaching of students.

The preoperative preparation of the surgical patient is very important. A critical survey should be made of each patient in order to evaluate the anesthetic and surgical risk. The stomach should be empty and premedication individualized in order to prevent over-doses of depressant drugs. Good equipment should be available. There must be no appreciable resistance within the gas machines and the carbon dioxide absorber should be efficient. Airways, suction equipment, oxygen fitted resuscitative equipment, vasoconstrictor drugs and adequate replacement fluids are "musts" in every operating room.

During anesthesia, it is important that anoxia be prevented. If it does occur, the anesthetist must be alert and able to recognize the signs immediately so that proper therapy can be instituted without delay. The signs commonly referred to as being caused by carbon dioxide accumulation are frequently signs brought on by the presence of anoxia. I refer to sweating, hyperpnea, elevation of blood pressure and increased pulse rate. The anesthetist who routinely observes these findings and dismisses the subject to his students as carbon dioxide excess is not only misinforming his students; he is toying with the fate of his patients.

Spinal anesthesia results in death to the patient, paralysis or damage resulting from anoxia far too frequently. Patients subjected to spinal anesthesia must be watched just as closely as those under general anesthesia. Safe drugs should always be selected and minimum doses used in a dilution great enough to prevent damage to the spinal cord. Blood pressure must be supported and if signs of respiratory failure develop, artificial respiration given immediately by the intermittent method of oxygen administration. It is a common sight in operating rooms where patients are being operated upon under spinal anesthesia to find no resuscitative equipment available or if it is available to find the oxygen cylinder turned off, and the rubber tubing, bag and face mask removed from the machine. A patient who develops respiratory paralysis from spinal anesthesia is likely to lose his life while the anesthetist is frantically looking for equipment and getting it in order.

Many patients develop pulmonary edema or pneumonia following the aspiration of stomach contents into the tracheobronchial tree. Death can occur very quickly following massive aspiration of vomitus. This complication occurs quite frequently during or immediately after delivery. Every delivery room should have effective suction equipment immediately available for tracheal aspiration and if gross vomitus has been aspirated into the patient's lungs, bronchoscopic aspiration is indicated.

Obstruction to the airway plays an important role in producing anoxia during anesthesia. The pharynx, trachea and bronchi must be

kept clear. This is especially true during surgical procedures on the lung. We are convinced that most deaths on the operating table during major thoracic surgical procedures are the result of obstruction and acute anoxia and not of vago-vagal reflexes. We have never seen a patient in whom we have thought procaine infiltration of the hilar structures was indicated. We have seen patients who would have lost their lives on the operating table had not immediate tracheobronchial aspiration been done, and at times it had to be done by direct vision through a bronchoscope. Every anesthetist who assumes the responsibility for anesthesia in thoracic surgery should be an expert bronchoscopist.

Death on the operating table during cyclopropane anesthesia is, we believe, an avoidable tragedy. The report from the Wisconsin General Hospital makes one of the strongest indictments of its use.

REFERENCES

1. Hoff, Hebbel E.: *Medical Progress; Physiology*, New England J. Med. **225**: 28-34 (July 3) 1941.
2. Waters, R. M., and Gillespie, N. A.: *Deaths in the Operating Room*, *Anesthesiology* **5**: 113-128 (March) 1944.
3. Gillespie, N. A.: *Death During Anaesthesia*, *Brit. J. Anaesth.* **19**: 1-16 (Jan.) 1944.
4. Courville, C. B.: *Untoward Effects of Nitrous Oxide Anesthesia with Particular Reference to Neurologic and Psychiatric Manifestations*, Mountain View, Calif., Pacific Press Pub. Assn., 1939.
5. Flagg, Paluel J.: *The Art of Anesthesia*, Philadelphia, J. B. Lippincott Co., 1939.
6. Clement, F. W.: *Nitrous Oxide and Oxygen Anesthesia*, Philadelphia, Lea and Febiger, 1939.
7. Mousel, L. H., and Essex, Hiram E.: *An Experimental Study of the Effects of Respiratory Stimulants in Animals under Pentothal Sodium Anesthesia*, *Anesthesiology* **2**: 272-280 (May) 1941.
8. Eastman, N. J., and Kreiselman, J.: *The Treatment of Experimental Anoxia with Certain Respiratory and Cardiac Stimulants*, *Am. J. Obst. & Gynec.* **41**: 260-267 (Feb.) 1941.
9. Eastman, N. J.; Dunn, R. B., and Kreiselman, Joseph: *The Relative Value of Pure Oxygen and of Carbon Dioxide Mixtures in Experimental Resuscitation*, *Am. J. Obst. & Gynec.* **36**: 571-577 (Oct.) 1938.
10. Schmidt, Carl F.: *Recent Developments in Respiratory Physiology Related to Anesthesia*, *Anesthesiology* **6**: 113-123 (Mar.) 1945.