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SOME ANESTHETIC PROBLEMS DURING THORACIC SURGICAL PROCEDURES

Karl L. Siebecker, M.D., and John T. Mendenhall, M.D.

with the technical assistance of
Howard Rasmussen and Sallie Loomans

This study was undertaken in order to compare several methods of assisting or controlling respiration during anesthesia for open thoracic surgical procedures.

Controlled, assisted, or artificial respiration by means of the "hand on the bag" is, in this country, the most popular means of maintaining anesthesia and overcoming the physical disturbances that arise when the thorax is opened (1). There are very definite advantages to this method and much to be learned from the "feel of the bag" by the experienced anesthetist. *If* adequate ventilation is maintained throughout the course of the anesthetic, it may be the best method available for "open" thoracic procedures.

The acid-base balance as determined by the arterial blood pH and pCO_2 is evidence of the adequacy of ventilation. The position of the patient (1), various anesthetic agents (2), and techniques have been blamed for causing a shift in the acid-base balance. It has been shown by Stead (3), by Patrick and Faulconer (4), and by Beecher (5, 6, 7) that decrease in *ventilation* is a cause of much of the difficulties encountered in anesthesia for "open" thoracic procedures.

The alert anesthesiologist has many signs on which he depends to guide him in preventing serious damage to his patient due to hypoxia. However, Comroe and Botelho (8) have shown that groups of competent observers, including anesthesiologists, were unable to recognize hypoxia in anesthetized patients until the blood oxygen saturation dropped to 70 per cent or below.

During the administration of an anesthetic, the patient who has excessive accumulation of carbon dioxide in the body presents no sign as obvious as cyanosis to warn us. Blood pressure elevations, variations in the pulse, changes in respiration, and, of course, muscle twitching occur relatively late. Recent studies by means of the mass spectrometer by Buckley (9) and by Miller (10) and their group have shown that, with common anesthetic techniques for nonthoracic procedures, allowing the patient to breath spontaneously and unassisted,

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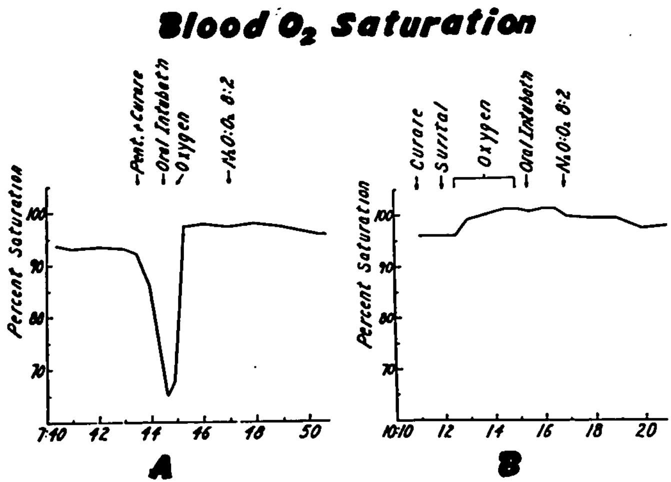
carbon dioxide is retained in the patient more than the anesthesiologist realized, or would allow, if he were able to judge by any clinical signs.

To obtain quietness of the operative field, we prefer to depend on controlled respiration to keep the diaphragm inactive. As Guedel showed in 1934 (11) and Waters described in 1936 (12), this is accomplished by hyperventilation, which lowers the carbon dioxide level in the blood and decreases or eliminates the respiratory drive. Rarely, when unable to accomplish this, curare in larger doses may be used to paralyze the diaphragm.



A. Intubation without administration of oxygen. **B. Intubation when oxygen has been administered previously.**

FIG. 1.

With the advance of electronics, various mechanical devices have become available which facilitate clinical investigation. The ear oximeter presents continuous evidence of blood oxygen saturation. Figure 1(A) is a graph of readings taken during an anesthetic showing how the manipulations and delay during intubation can cause a severe decrease in oxygenation. Figure 1(B) shows how administration of adequate oxygen before intubation prevents such a fall.

A practical means of determining variations in the patient's acid-base balance during the course of the anesthetic is desirable. For this purpose, we have been using an infrared absorption type of gas analyzer,* which continually measures the carbon dioxide in the respired atmosphere (13). As shown in figure 2, a small continuous sample is sucked through a sampling cell by means of a small catheter which may be placed in any part of the respiratory-anesthesia system. Readings taken with this analyzer reflect the actual concentration of the carbon dioxide content of whole blood, and allow a minute-to-minute estimation of the acid-base balance in the body.

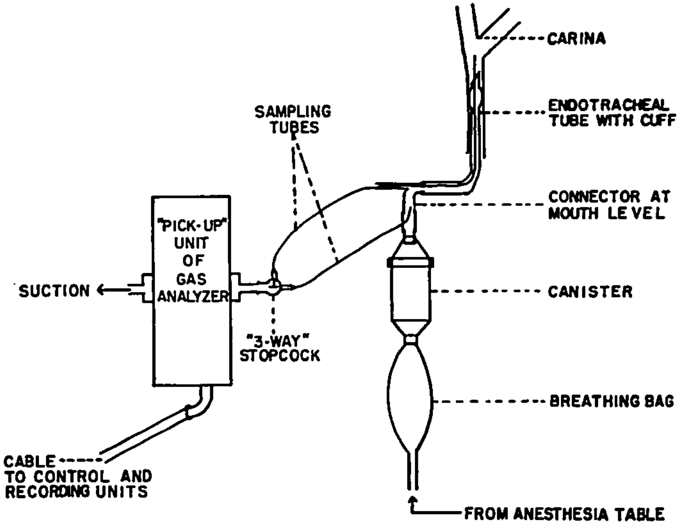


FIG. 2.

There are certain situations, severe emphysema among them, when some mechanical means of assisting or controlling respirations may be of great value. Mechanical methods of assisting or controlling respiration, and artificial respiration by mechanical means during open thoracic procedures, have had their proponents and opponents. Since Crafoord (14) described his Spiro-pulsator, mechanical methods have been much more in use in Europe (15–17) than in the United States (18, 19). It must be remembered that machines are always subject

* Liston-Becker Company, Stamford, Connecticut.

to mechanical failure. The feeling in this country has been that the "hand on the bag" can give the anesthesiologist a large amount of information that he would not be able to receive by means of a machine (7). It was also thought by most that it is easier to coordinate with the activities of the surgeon when the respiration is assisted or controlled manually. The choice of anesthetic agents, and the method of administering the anesthetic, semiclosed, to-and-fro absorption and circle absorption, are variable depending on the preference of the anesthesiologist and the surgeon. Early in this series of 608 cases, there was lack of extra help, and, since we wanted to have time to make physiological recordings, some other means than the anesthesiologist's "hand on the bag" had to be made available. The method developed for applying the mechanical means (20) is shown in figures 3(A) and 3(B). The apparatus is connected to the endotracheal tube and in 486 of the last 501 cases a Carlens double lumen catheter has been used. A side arm is connected to a double-barreled water manometer having a water level of 25 cm. on the positive side and 10 cm. on the negative side, both as a guide to the pressures imposed and as a safety measure to prevent excess pressure or suction on the patient's respiratory system. A Sword valve is now placed between the bottle and the to-and-fro canister. Originally, this blow-off valve was next to the endotracheal connector. A project is now being conducted to determine the effect of the different valve positions. The breathing bag is encased in a 3- or 5-gallon laboratory bottle with an opening at the bottom to which the mechanical pumps are connected.

The pressure curves taken from inside the endotracheal tube at mouth level are shown in figure 4. Atmospheric pressure is shown as the zero point on each strip. All were taken on the same patient within a few minutes of each other.

The first strip shows the pressure curve during the use of a positive-negative resuscitator with the pressure applied to the anesthetic breathing bag inside the bottle. The values ranged from + 21.23 cm. to − 5.79 cm. water pressure when this curve was recorded. This can be varied up to 25 cm. positive water pressure and 10 cm. negative by adjusting the blow-off valve or changing the rate of flow of the anesthetic gases. The flexibility of the pressure range is a definite advantage and can be adjusted to fit the expansibility of the lungs of each individual case. We have found this flexibility particularly valuable in emphysematous patients.

The next strip in figure 4 shows the pressure ranges obtained when using manual inflation, and illustrates what we consider a fairly good respiratory pattern, in that adequate time is allowed for spontaneous deflation of the lungs. The time ratio of expiration to inspiration is 3½ to 1.

The curve in the third strip of figure 4 illustrates the pressure ranges during the use of an intermittent positive pressure valve. With this particular valve, the pressure never drops to zero and therefore is actually a varying positive pressure technique, which we do not consider desirable and to which the surgeons definitely object because the lung is hyperinflated all of the time.

The last strip in figure 4 shows us the pressure ranges with a positive-negative valve connected directly to the carbon dioxide absorption canister. The movement of the lung and the mediastinum is not as easily controlled this way as when the bottle is interposed, again causing interference in the surgical field.

In this series of 608 cases, 50 were done by manual inflation alone, 54 with intermittent positive pressure, and 504 with positive-negative pressure, using 2 different valves. There were 403 arterial blood samples taken in 151 cases, averaging about 3 samples per case. Most cases were followed with the Liston-Becker Gas Analyzer taking a continual sample of the carbon dioxide in the tracheal atmosphere. An ear oximeter was in use during the course of the anesthetic in the last 389 cases.

The first 400 patients received only scopolamine for preanesthetic medication and all were anesthetized with thiobarbiturate, curare, and nitrous oxide. This routine procedure was followed in an effort to reduce the variables as much as possible.

A few patients in each group, when turned to the lateral position,

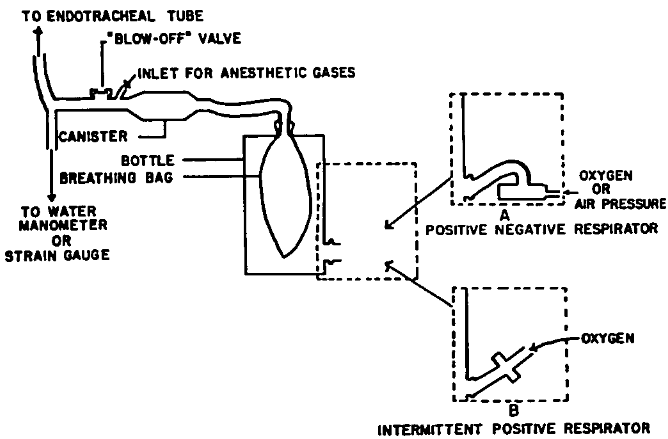


FIG. 3A.

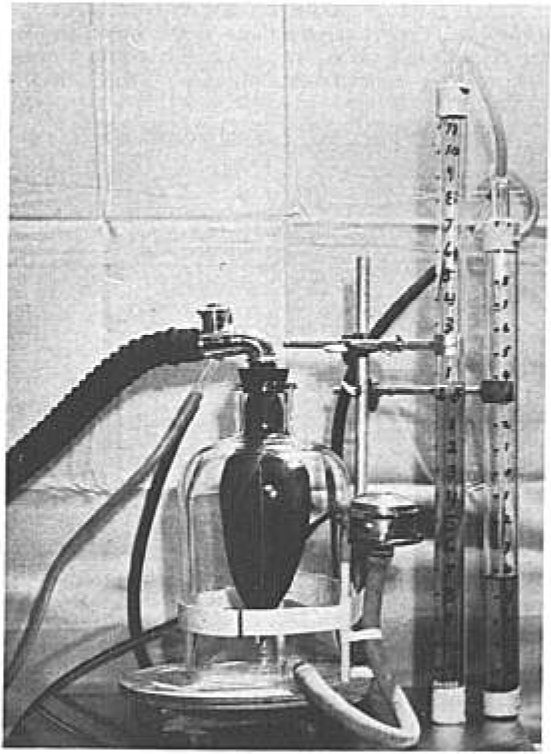


FIG. 3B.

were allowed to breathe spontaneously until a blood sample had been taken and analyzing apparatus connected. In many cases, this breathing appeared to be adequate, but the data in figure 5 indicate that it was not. The pH of the arterial blood was measured within a few minutes after the sample was taken by means of a Cambridge glass electrode pH meter, which is located in the operating suite. The whole blood carbon dioxide content was analyzed by the Van Slyke manometric method (21). The arterial blood pCO_2 was then calculated from the nomogram of Singer and Hastings (22). The average values of the blood samples taken during this early period of spontaneous respiration are indicated in the first column, and, of course, showed similar readings for each of the 3 methods. As soon as assisted, artificial, or controlled respiration was begun, conditions improved markedly. This is shown in the second column, and the average whole blood pCO_2 was then markedly lowered in all 3 groups. It is remark-

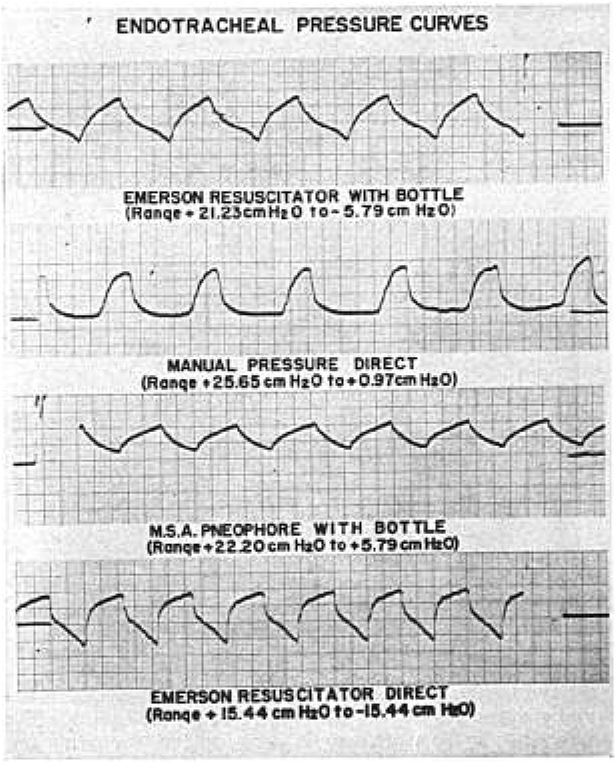


FIG. 4.

able how soon the blood levels change when adequate ventilation is established. Some of these samples were taken within less than 5 minutes after the initial sample.

Blood samples taken after the pleura was opened are divided into 2 categories—those when both lungs were in use and those when only one lung was being used. This was possible by means of clamping off one side of the Carlens double lumen catheter. Here it can be seen that all methods appear to give adequate ventilation when both lungs were in use, as evidenced by an average pCO_2 within normal limits for each of the indicated methods of assisting respiration (fig. 5). When only one lung was being used, in order to give the surgeon more room to work, or to allow aspiration of pus, blood, or tracheal secretions, the pCO_2 level did not increase significantly in the positive pressure or manual methods. The pCO_2 of the blood samples, taken during one lung respiration using the positive-negative system, showed

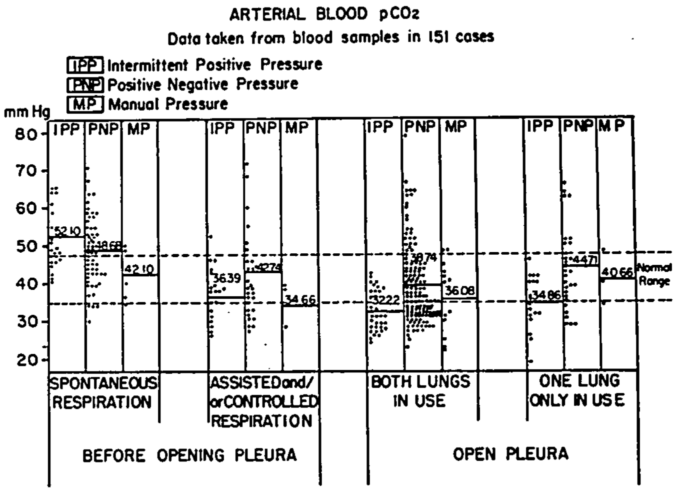


FIG. 5.

an elevation after fifteen to twenty minutes of use. So it can be seen that the use of only one lung for moderate periods of time in order to facilitate the surgeon's work, or to aspirate débris from the bronchi, probably is justified. The normal range for arterial blood pCO_2 is considered to be 35 to 47. Our average figure for the period using only one lung is 45, and even though this is higher in the positive-negative pressure group, it is within the normal range and much lower than pCO_2 levels reported by some workers during anesthesia for thoracic procedures under the best of conditions and using both lungs (23).

Figure 6 shows the average oxygen content of the blood samples taken during spontaneous respiration and during assisted, controlled, or artificial respiration, in the same order as the data presented in figure 5. It would appear from the average oxygen content of the blood samples taken during spontaneous respiration that the oxygenation was adequate under these conditions. However, it should be noted that there were some dangerously low readings in this group that were overbalanced in the averages by some very high ones. Since beginning routine use of the ear oximeter, these low readings are infrequent because they are detected quickly and remedied. The oxygen content appears adequate under all conditions of assisted or controlled respiration and is similar for all 3 methods.

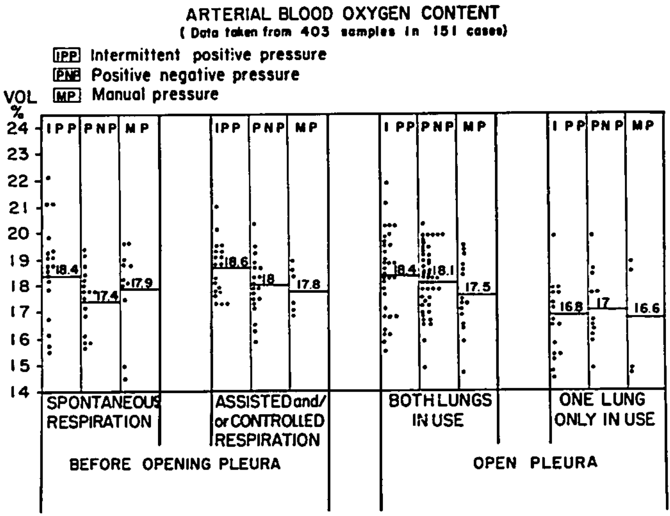


FIG. 6.

Aspiration of secretions, blood, or pus is a frequent problem in anesthesia for thoracic procedures and is performed much easier when using a double lumen endotracheal tube, since respiration may be maintained through one lung while the other bronchus is cleaned. Figure 7 shows the anatomical relations and the position of the Carlens tube when properly placed. The use of this relatively large, stiff, irregular tube brought up the question of possible trauma. We are studying this, at the present time, and to date have examined 178 patients at varying postoperative times and have found no evidence of granulomatous lesions or other permanent injury.

It would appear that, from a standpoint of adequate ventilation, the mechanical means of assisting or controlling respiration as used by us are satisfactory. We are continuing these studies and further investigations are in progress into the effects of each method on the circulation.

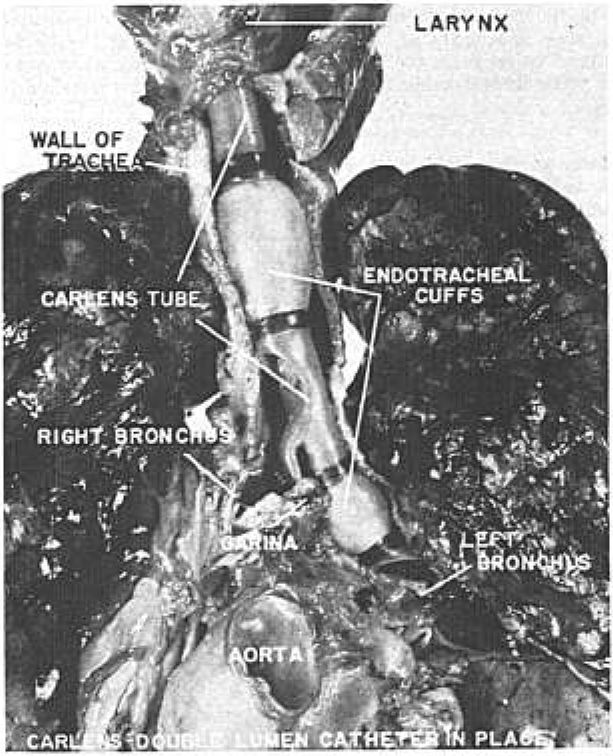


FIG. 7.

It should be pointed out that we are not advocating mechanical assistance of respiration for all open thoracic procedures, and it would be impractical where only occasional cases are done. We still believe that the "hand on the bag" is extremely valuable and have no hesitation in disconnecting our gadgets and using this relatively simple, effective method, either to evaluate the situation or, if necessary, when machines fail. Our 2 positive-negative valves have been in nearly daily use throughout this series of cases, and also used in the dog laboratory. They have required a minimum of service or repair.

In conclusion, it might be added that our surgeons prefer the positive-negative method because of the ease of retracting the lung and the general quietness of the operative field. The use of the Carlens tube facilitates the closure of bronchi without a clamp on the bronchial stump. The surgeons feel that this lack of damage to the stump may be of value in decreasing the incidence of bronchopleural fistulas.

SUMMARY

Some of the problems occurring during anesthesia for "open" thoracic procedures are enumerated. A method of mechanical aid to assist or control respiration is described. The data from 403 arterial blood samples from 151 of 608 cases indicates satisfactory results for the method used.

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REFERENCES

1. Beecher, H. K.: Principles, Problems and Practices of Anesthesia for Thoracic Surgery, Springfield, Illinois, Charles C Thomas, 1952, p. 44.
2. Taylor, F. H., and Roos, A.: Disturbances in Acid-base Balance During Ether Anesthesia, J. Thoracic Surg. 20: 289 (Aug.) 1950.
3. Stead, W. W., Martin, F. E., and Middlebrook, J.: Practical Method for Detection of Early Respiratory Acidosis During Thoracic Surgery, J. Thoracic Surg 27: 306 (March) 1954.
4. Patrick, R. P., and Faulconer, A., Jr.: Respiratory Studies During Anesthesia with Ether and with Pentothal Sodium, Anesthesiology 13: 252 (May) 1952.
5. Beecher, H. K.: Some Problems of Acid-base Equilibrium During Anesthesia with Particular Reference to Thoracic Surgery, Anesth. et Analg. 9: 16, 1952.
6. Beecher, H. K., and Murphy, A. J.: Acidosis During Thoracic Surgery, J. Thoracic Surg. 19: 50 (Jan.) 1950.
7. Beecher, H. K.: Principles, Problems, and Practices of Anesthesia for Thoracic Surgery, Springfield, Illinois, Charles C Thomas, 1952, p. 15.
8. Comroe, J. H., and Botelho, S.: Unreliability of Cyanosis in the Recognition of Arterial Anoxemia, Am. J. M. Sci. 214: 1 (July) 1947.
9. Buckley, J. J., Van Bergen, F. H., Dobkin, A. B., Brown, E. B., Jr., Miller, F. A. and Varco, R. L.: Postanesthetic Hypotension Following Cyclopropane; Its Relation to Hypercapnia, Anesthesiology 14: 226 (May) 1953.
10. Miller, F. A., Hemingway, A., Nier, A. O., Knight, R. T., Brown, E. E., and Varco, R. L.: Development of, and Certain Clinical Applications for, Portable Mass Spectrometer, J. Thoracic Surg. 20: 714 (Nov.) 1950.
11. Guedel, A. E., and Treweek, D. N.: Ether Apnoeas, Anesth. and Analg. 13: 265 (Nov.-Dec.) 1934.
12. Waters, R. M.: Carbon Dioxide Absorption from Anaesthetic Atmospheres, Proc. Roy. Soc. Med. 30: 11 (Nov.) 1936.

13. Siebecker, K. L., Mendenhall, J. T., and Emanuel, D. A.: Carbon Dioxide in Anesthetic Atmospheres as Measured by the Liston-Becker (infra-red absorption) Gas Analyzer, J. Thoracic Surg. 27: 468 (May) 1954.
14. Crafoord, C.: Pulmonary Ventilation and Anesthesia in Major Chest Surgery, J. Thoracic Surg. 9: 237 (Feb.) 1940.
15. Nosworthy, M. D.: Anaesthesia for Thoracic (excluding cardiac) Operations, Anaesthesia 6: 211 (Oct.) 1951.
16. Esplen, J. R.: New Artificial Respirator, Brit. M. J. 2: 896 (Oct. 25) 1952.
17. Macrae, J., McKendrick, G. D., Claremont, J. M., Sefton, E. M., and Walley, R. V.: Clevedon Positive-Pressure Respirator, Lancet 265: 971 (Nov. 7) 1953.
18. Bunnell, S.: Positive Pressure for Thoracic Surgery with Nitrous Oxide-Oxygen Anesthesia, J.A.M.A. 58: 835, 1912.
19. Mautz, F. R.: Mechanism for Artificial Pulmonary Ventilation in the Operating Room, J. Thoracic Surg. 10: 544 (June) 1941.
20. Siebecker, K. L.: Use of Mechanical Positive-Negative, Intermittent Positive and Manual Pressure in Anesthesia for "Open" Thoracic Procedures, Federation Proceedings, 13: 1328, 1954.
21. VanSlyke, D. D., and Neill, J. M.: Determination of Gases in Blood and Other Solutions by Vacuum Extraction and Manometric Measurement, Internat. J. Biol. Chem. 61: 523, 1944.
22. Singer, R. B. and Hastings, A. B.: Improved Clinical Method for Estimation of Disturbances of Acid-base Balance of Human Blood, Medicine 27: 223 (May) 1948.
23. Ellison, R. G., Ellison, L. T., and Hamilton, W. F.: Analysis of Respiratory Acidosis During Anesthesia, Ann. Surg. 141: 375 (March) 1955.