THE MANAGEMENT OF ANESTHESIA FOR CONGENITAL HEART OPERATIONS IN CHILDREN

ALVIN J. HARRIS, M.D.*

San Francisco, California

Received for publication July 15, 1949

WITH the development of cardiac surgery in recent years the anesthetic management of these patents has assumed great importance. There is no denying the fact that the increase in types of surgical procedures performed within the thoracic cavity could not have been accomplished without advances in anesthesiology. The days of rapid traumatic thoracic surgery are gone. It is now possible for surgeons to operate six to ten hours within the thoracic cavity with little fear of shock or death from anesthesia *per se.*

One of the factors which make possible prolonged intrathoracic operations is controlled respiration. By its use the disturbing effects of an open chest on the pulmonary and cardiovascular system are obviated.

Another factor contributing to prolonged chest surgery is the use of a relatively innocuous and nonexplosive inhalation agent, namely nitrous oxide (4).

Curare (5, 8) has proved to be a valuable supplement to anesthesia in thoracic surgery as it aids considerably in the performing of controlled respiration. It also allows for a quiet operative field which is so important in vascular surgery.

The purpose of this paper is to describe in detail the management of anesthesia using nitrous oxide and controlled respiration during operations for the correction of tetralogy of Fallot and patent ductus in children. This technic was developed and described by Stephens, Harroun and Beckert (8) in the Department of Anesthesiology, University of California Medical School. I frankly admit not having used cyclopropane or ether, the other commonly used anesthetics for these procedures and am thereby not attempting to compare the procedure to be described with any other type. Such anesthesia has been employed in 25 cases. So small a series of cases is hardly enough for statistical evaluation. This paper, then, should be considered a preliminary report.

METHOD

Premedication and Basal Narcosis.—Because nitrous oxide is a weak anesthetic agent it is necessary to employ other drugs to obtain

* From the Department of Anesthesiology, Mount Zion Hospital, San Francisco, California.

a basal narcosis before nitrous oxide can be used in concentrations that will still permit adequate oxygen supply to the patient. As Cullen (1) pointed out, the choice of a basal narcotic or basal anesthetic agent depends on the expected duration of the operation. For short procedures sodium pentothal is used; for moderately long procedures morphine or allied drugs; for long procedures avertin is recommended.

Avertin is used almost routinely in all the children. The dosage is 100 to 150 mg. per kilogram of body weight. Recently, however, intravenous demerol has replaced avertin because the duration of the surgical procedure has been shortened. The average dosage is 10 to 15 mg. (⅙ to ¼ grain) at three-fourths to one and a half hour intervals.

Preoperatively morphine and scopolamine are administered one hour prior to operation. It has been found that those patients with tetralogy of Fallot tolerate morphine well. The drug is used in the treatment of convulsive attacks which are often seen in these patients. Children from 2 to 4 years of age receive morphine sulfate, 1/12 grain (5 mg.) and scopolamine, 1/300 grain (0.2 mg.); from 4 to 8 years morphine sulfate 1/10 grain (6 mg.) with scopolamine 1/250 grain (0.25 mg.); from 8 to 12 years morphine sulfate 1/8 grain (8 mg.) with scopolamine 1/200 grain (0.3 mg.).

It is thought that large doses of scopolamine protect against the effects of vagal stimulation which might occur owing to traction on the great vessels or the hilus of the lung.

Induction.—The child is brought to the operating room and the effects of the morphine and scopolamine are evaluated. The dosage of avertin may be reduced to 90 or 80 mg. per kilogram if the child is sleeping and cannot be easily aroused. If the child is old enough to cooperate, avertin is then administered by rectal tube at a gravity flow rate. After waiting three to five minutes for the beginning effects of the avertin, a face mask is applied and cyclopropane administered by closed system for a period of three to five minutes, that is, to deep second or light third plain anesthesia, and oral endotracheal intubation is performed. If the child is uncooperative cyclopropane is administered by closed system and avertin instilled by a nurse as soon as the child is quiet. Cyclopropane is continued until the desired stage of relaxation is obtained at which time oral endotracheal intubation is performed. Inflation-cuffed endotracheal tubes are not used. It is thought that these add additional trauma to the trachea in children. A variety of rubber endotracheal tubes is lubricated and ready and the largest size possible is introduced through the vocal cords so that only a small amount of gas will escape around the tube during controlled respiration. Water soluble lubricant is used to safeguard against lipoid pneumonia.

A Leigh valve with rubber bag reservoir distal to the valve is then attached to the endotracheal tube and nitrous oxide and oxygen are fed into the rubber bag (6). A mixture of 75 per cent nitrous oxide and 25 per cent oxygen is delivered, the rate of flow not being important at

this time as the Leigh valve prevents rebreathing. The rate of flow is adjusted to keep the rubber bag moderately full. If respiratory depression is noted with shallow and slow respiration the nitrous oxide is discontinued and 100 per cent oxygen administered.

Maintenance.—The child is then put in position for surgery, prepared and draped, and a Lindeman needle inserted in the saphenous vein which has been cut down upon. A 1/6 molar sodium lactate solution is started intravenously slowly at the rate of from 10 to 30 drops a minute. Its purpose is to supply replacement fluids, and to provide a route for intravenous administration of morphine, demerol and curare. A unit of blood is also attached and ready if bleeding becomes profuse.

The patient's reaction to the skin incision is carefully observed. Morphine in small doses, 1/16 grain (4 mg.) to 1/12 grain (5 mg.), or demerol, 10 to 15 mg., is added intravenously if the child moves considerably.

From three to five minutes before the pleural cavity is opened curare, 20 to 40 units, is administered intravenously. The Leigh valve and rubber reservoir bag are removed and an Ayres tube (T tube) inserted distal to the endotracheal catheter. The depth and rate of respirations are observed. Artifical respiration is started when apnea is evident. If the curare has not affected the respirations, additional curare is administered. The respirations are then controlled by shutting off the open end of the Ayres tube until the lungs are inflated and then releasing the pressure. Exhalation follows as a result of the elastic recoil of the chest. An attempt is made to establish controlled respiratory movements similar in rate and depth to those prior to the administration of curare before the pleural cavity is opened. A water manometer indicating the amount of pulmonary pressure is not necessary if the character of respiration has been carefully observed (3). It is always necessary to increase the rate of flow of gases at this time, maintaining the same percentage of nitrous oxide, however. At times a total flow of 8 to 12 liters per minute is necessary especially if considerable gas escapes from around the endotracheal catheter. If it is desired to increase the rate of controlled respiration, even greater flows of gases will be necessary. It is important that the rate of gas flow be high so that the inspiration phase can be accomplished quickly which in turn allows for a long expiratory phase and expiratory pause. This is important in allowing for adequate and complete filling of the heart (7).

In order to aid in the exposure of the heart and great vessels after opening the chest, depth of respiration is decreased, partially collapsing the lung, while the rate is increased to 20 to 30 per minute. After the lung has been retracted and dissection of the great vessels started, depth of respiration is increased but not to the point of interfering with exposure. It is obvious that the anesthetist must constantly observe the open chest and the movements of the exposed lung at all times.

Upon opening the chest, deeping of peripheral cyanosis is observed

in patients with tetralogy of Fallot (3). The gaseous mixture is then adjusted to 50 per cent nitrous oxide and 50 per cent oxygen. When the pulmonary vessels are clamped preparatory to anastomosis during the Blalock operation, 100 per cent oxygen is given. There is little fear that discontinuing nitrous oxide will cause the patient to move or cough as the great vessels are comparatively insensitive. The basal narcosis of avertin combined with morphine provides adequate anesthesia for this portion of the operation. Fifty per cent nitrous oxide is again administered after the anastomosis is completed.

Repeated doses of curare may be necessary. If jerking diaphragmatic movements are observed, 20 to 30 units is given. Occasionally, however, the entire intrathoracic portion of the operation has been performed with only the initial dose of curare. Controlled respiration in these cases was probably aided by the artificial tachypnea, which lowered the carbon dioxide tension of the blood, and also aided by the administration of morphine which decreased the sensitivity of the respiratory centers (2).

The lungs are reinflated every hour during the intrathoracic portion of the operation and also preparatory to closure of the pleural cavity. A small rubber catheter is inserted into the thoracotomy incision at its uppermost point and the other end kept under a small bowl of water. Controlled respiration is maintained until the catheter is removed. As the chest closure becomes air tight, bubbling occurs at the end of the catheter. When it is felt that the chest wall is tightly approximated, the lungs are expanded at a slightly greater force until all air is expelled from inside the chest and the catheter is then removed. Controlled respiration and the administration of nitrous oxide are stopped and spontaneous respirations are awaited. It may take five to ten minutes before spontaneous respiratory movements show adequate tidal exchange. During this time respirations are assisted with oxygen, keeping careful watch on the pulse and blood pressure in order to prevent an undue period of hypoxia.

Recovery.—The child usually responds by moving as the skin sutures are placed. While dressings are being applied the pharynx and trachea are aspirated and if reflexes are active, the endotracheal catheter is removed. If the depressant effects of avertin and morphine are still present, the removal of the endotracheal tube is delayed. The patient is returned to bed and placed in an oxygen tent in those cases in which the Blalock operation has been performed. Very little sedation or narcotic is needed during the immediate postoperative period owing to the lasting effects of the avertin.

Complications.—There has been one case of severe tracheitis believed due to a contaminated endotracheal tube. Tracheotomy was not necessary. Another patient died from prolonged respiratory obstruction caused by laryngeal edema. Therapeutic measures were administered too late. In this case it is believed the endotracheal tube was too large.

Cardiac irregularities which reportedly are frequent (9) have been seen rarely. There has been one case of tachycardia which developed upon incising the pericardium and exploring the base of the heart. This lasted fifteen minutes and stopped spontaneously. There has been only one death in the operating room due to cardiac arrest. It occurred in an 18 month old child who was undergoing exploration preparatory to the Blalock anastomosis.

DISCUSSION AND SUMMARY

A method of administering anesthetic agents to children undergoing cardiac surgical procedures has been presented. This technic, although complicated, has certain advantages. By using nitrous oxide combined with curare and controlled respiration, a quiet operative field is obtained which also allows for the use of cautery within the chest.

The anesthetic mixture supplied to the patient always contains at least 25 per cent oxygen. When the pleural cavity is opened the mixture contains 50 per cent oxygen and when an anostomosis is being performed 100 per cent oxygen is given. This high oxygen content is made possible by the use of heavy basal narcosis.

Emphasis should be placed on the method of administering controlled respiration. A short, rapid inspiratory phase followed by a longer expiratory phase with expiratory pause is most desirable. Cardiac filling is not impeded during this expiratory period so long as the intrathoracic pressure is atmospheric. Positive intrathoracic pressure such as is seen during the inspiratory phase of controlled respiration does impede the filling of the heart.

Although cardiac irregularities have been infrequently observed, it may be that they have been overlooked. Probably more careful observation of the pulse together with electrocardiagram tracings during anesthesia would reveal more cardiac irregularities.

REFERENCES

1. Cullen, S. C.: Anesthesia in General Practice, Chicago, The Year Book Publishers, Inc. 1946. p. 81.
2. Goodman, L., and Gilman, A.: The Pharmacological Basis of Therapeutics, New York, The Macmillan Company, 1941. p. 192.
3. Harmel, M. H., and Lamont, A.: Anesthesia in the Surgical Treatment of Congenital Pulmonic Stenosis, Anesthesiology, 7: 477–498 (Sept.) 1946.
4. Harroun, P.; Beckert, F. E., and Hathaway, H. R.: Curare and Nitrous Oxide Anesthesia for Lengthy Operations, Anesthesiology 7: 24–28 (Jan.) 1946.
5. Harroun, P., and Hathaway, H. R.: Use of Curare in Anesthesia for Thoracic Surgery; Preliminary Report, Surg., Gynec. & Obst. 82: 229–231 (Feb.) 1946.
6. Leigh, M.D., and Belton, M. K.: Pediatric Anesthesia, New York, The Macmillan Company, 1948. p. 51.
7. Motley, H. L., Intermittent Positive Pressure Breathing; Means of Administering Artificial Respiration in Man; Council on Physical Medicine, J. A. M. A. 137: 370–382 (May 22) 1948.
8. Stephens, H. B., Harroun, P., Beckert, F. E.: Use of Curare in Anesthesia for Thoracic Surgery, J. Thoracic Surg. 16: 50–61 (Feb.) 1947.
9. Ziegler, R. F.: The Cardiac Mechanism During Anesthesia and Operation in Patients with Congenital Heart Disease and Cyanosis, Bulletin of the Johns Hopkins Hospital 83: 237–273 (September) 1948.