TECHNICS IN PEDIATRIC ANESTHESIA—THE NONREBREATHING METHOD * †

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As more and more recognition is given to the premise that good anesthesia means minimal disturbance of the patient's basic physiologic functions, greater emphasis is placed upon the technics whereby narcotic drugs are administered. Today, good anesthesia implies utilization of agents by such methods and combinations so that no interference occurs in the metabolic functions of the liver, kidney or adrenal glands; it supposes adequate but not overabundant oxygenation, associated with proper elimination of carbon dioxide; it means maintenance of cardiac dynamics within functional limits for the patient concerned; and finally it strives to preserve the internal electrolytic and autonomic balance of each individual.

Physiologic Factors

In children, the fundamental problems presented are peculiar because of the small size of many of the anatomic structures. When, for example, the respiratory pathway is considered, it is evident how easily upper respiratory obstruction may become a real threat to the anesthetist. Hyperplasia of adenoid tissue and enlarged tonsils may be superimposed over a larynx whose diameter is so small that it cannot combat interference from above. The bones of the thoracic cage are so malleable and frail that even a minor obstruction will create sufficient negative pressure from within to produce substernal indrawing and a "rocking boat" respiration. It has been stated that infants predominantly are abdominal breathers, but in actuality this predominance of diaphragmatic action becomes evident only in the presence of some type of upper respiratory obstruction. Under light planes of anesthesia loss of intercostal action in the child means respiratory obstruction or fatigue of the intercostal muscles.

Fatigue of the intercostal muscles is easy to understand when thought is given to their immaturity in the child. If it is remembered how quickly the well-developed muscles of an adult's arms become sore

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and tired when he carries 10 pounds of sugar for half-a-mile, it can be realized how in an unsuspected manner an obstruction or rapid respiratory rate may quickly bring fatigue and lessened intercostal action.

Of pertinent significance to the anesthetist also is the small exchange of gases which occurs with each respiration. Here, a delicate balance is established which permits little interference in its function. If tidal exchange is diminished by obstruction, depressant agents, muscular fatigue or rapid shallow respirations, the altered physiology

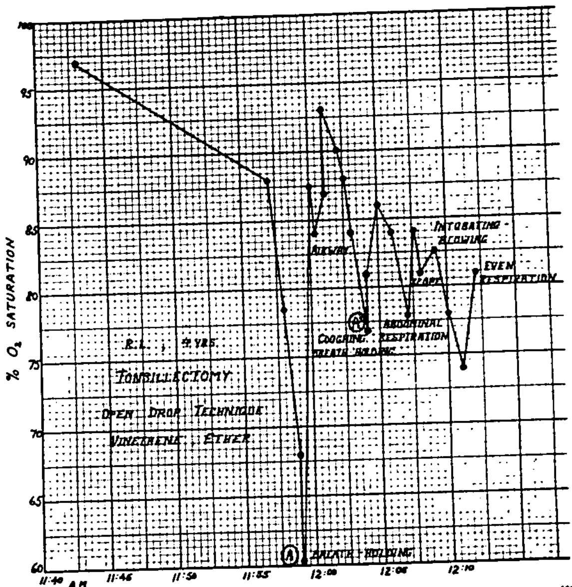

FIG. 1. Oximeter record of patient during vinethene-ether induction for tonsillectomy. Note acute fall of oxygen tension with breath-holding and gradual fall during induction period.

is quickly reflected in the patient. The narrow margin of error allowable is emphasized when the small amount of residual air available in the tiny lungs is considered.

The foregoing considerations focus attention on the fact that technics employed for pediatric anesthesia cannot be crude. Attention must be devoted to detail. What may seem like a small deviation from normal to an adult observer may mushroom into spreading disaster for the child. Some of the potential sources of trouble may be noted under the following headings:

(1) Obstruction of the airway. This has already been mentioned but cannot be stated too often. Even a minor obstruction lessens tidal exchange, increases the work expended by the child, enhances fatigue and produces anoxia. Breath-holding, which is akin to obstruction, will lower the arterial oxygen saturation to dangerous levels in a short period of thirty seconds (fig. 1) because of the small amount of residual air present in the lungs. Inadequate movement of the thoracic cage or suprasternal and substernal indrawing in light planes of anesthesia is an indication of respiratory obstruction. It will become pyramided unless efforts are made to overcome it. If improvement does not appear with proper holding of the jaw, insertion of airways, aspiration of secretions or deepening of anethesia, there should be no hesitation in alleviating it with an endotracheal tube. Anoxia is the commonest cause of death in anesthetized children.

FIG. 2. This face mask as employed in the partial rebreathing technic has a dead space of 250 cc.

(2) Mechanical dead space. The small tidal exchange in children, often rendered less by quiet respirations under anesthesia, impresses the anesthesiologist with the inadvisability of increasing dead space with anesthetic apparatus. When it is known that a face mask, such as pictured in figure 2, has a capacity of 250 cc., the possibility of rebreathing becomes manifest.

(3) Accumulation of carbon dioxide. This problem is linked to some extent with that of dead space, for whenever the latter is found there will be a concomitant increase in the concentration of carbon dioxide. Respirations which are depressed by anesthetic agents or obstructed in any way will also lead to retention of carbon dioxide.

The gaseous acidosis thus established may interfere seriously with the internal metabolism of the child, produce an unwarranted hypertension and induce a rapid respiratory rate which leads to early fatigue of the respiratory muscles. It is sometimes difficult to prevent the onset of a metabolic acidosis in a child but gaseous acidosis can be avoided with proper technics.

(4) Resistance in apparatus. The relatively weak respiratory musculature of the infant and child demands that he be supplied with anesthetic gases without extra effort on his part. If a 4 year old child is anesthetized by means of a circle absorption apparatus, the resistance inherent in the accordion tubes, directional valves and soda lime will be sufficient to produce, within thirty minutes, a picture similar to upper respiratory obstruction; namely, indrawing of the thoracic cage during inspiration and labored breathing. This, in time, will diminish tidal exchange, lead to a rapid respiratory rate and in the end produce a pale, sweating, worn-out patient. The energy of the child should be left available to combat the strains and stresses of the operative procedure, rather than be dissipated on the vicissitudes of the anesthetic technic.

Technics

It is worth while to review briefly how the technics employed in pediatric anesthesia conform with the principles already enumerated.

(1) Open drop technic. The vaporization of ether on an absorbent mask which covers the face is one of the oldest and probably the commonest method of administering anesthesia to children. This method is popular because of the safety of ether as an agent and because the necessary apparatus is simple and does not create much resistance to respiratory exchange. If this technic is used without embellishment, however, a situation is created in which the partial pressure of oxygen inhaled by the patient falls considerably below that in the air. As pointed out in an excellent article by Faulconer (1), this is reflected by lowering of the arterial oxygen saturation. The causes of this decrease in oxygen tension are twofold: first, the inhaled ether vapor occupies a volume in the inspired mixture which varies from 10 to 12 per cent during induction to 4 to 6 per cent during maintenance. Second, the area between the mask and the face is a potential dead space and a portion of each inhalation will consist of previously expired air which contains about 4 per cent carbon dioxide and only 16 per cent oxygen. Both these factors will reduce the oxygen content of the air which is inspired by the patient. These disadvantages can be overcome by allowing 100 per cent oxygen to flow in under the mask at a rate of 500 to 1500 cc. per minute, according to the age of the child. A further drawback to this technic is that only one agent can be used to maintain narcosis, and this an agent which produces metabolic acidosis when used in relaxing concentra-

tions. Moreover, it does not allow for the flexibility of aiding or assisting the patient's exchange should the respirations become depressed, fatigued or otherwise inefficient.

(2) Partial rebreathing, or fractional technic. Commonly used in Great Britain, this method involves essentially a high flow of gases, usually nitrous oxide and oxygen, and a reservoir bag situated near the face-mask, with an exhalation valve on the angle piece of the mask (fig. 2). In children, this technic is practical only if the flow of gases per minute is at least equal to, and preferably greater than, the minute volume of the patient. Even with this proviso, accumulation of carbon dioxide is a constant hazard because of the inherent dead space under the face mask and because there is no mechanism to prevent exhaled gases from flowing backward into the reservoir bag. When this technic is employed with intravenous pentothal, the clinical signs of retention of carbon dioxide may be masked and the anesthetist lulled into a false sense of security. Frequent emptying of the reservoir bag is a useful, prophylactic measure to avoid this danger. The principal advantage of this technic for children is the minimal resistance to respiration which is encountered throughout the system.

(3) Total rebreathing, circle and to-and-fro absorption. It has already been stated that the resistance encountered in a circle absorption apparatus in a short period of time will alter the physiologic balance of the child. It is unwise to subject any child under 8 years of age to such a technic unless assistance is given to the respiratory exchange throughout the entire procedure. A to-and-fro absorption system has only the resistance of the soda lime to surmount but even this is far from negligible in infants under 2 years of age. The mechanical disadvantage of keeping soda lime fresh and 100 per cent effective is also a problem in some cases. The to-and-fro system is satisfactory in children over 2 years of age when soda-lime canisters can be changed frequently without losing the anesthetic mixture, and when the patient's respirations are assisted frequently to avoid retention of carbon dioxide within the lungs and blood stream. (fig. 3).

(4) Combination of partial rebreathing and absorption technics. If the partial rebreathing system is modified by placing a soda-lime canister between the face piece and the reservoir bag, the equivalent of a to-and-fro absorption system results. Maintenance of a moderate flow of gases—1 to 4 liters per minute—lessens the resistance of the circuit and diminishes the hazard of accumulation of carbon dioxide. This is the technic recently recommended by Beecher. (2) It is a satisfactory method, particularly if an endotracheal tube connected directly to the soda-lime canister is substituted for the face mask.

(5) Ayre's, or insufflation technic. In 1937, a great step forward in pediatric anesthesia was made when Ayre (3) introduced his T-tube, which has one end inserted into the endotracheal tube, one end con-

nected to the source of gases and the third end open to the air. Relatively high flows of gases are used, and there are no valves or other obstructions to inspiration. Dead space is reduced to a negligible amount. One possible disadvantage is that constant insufflation is not physiologic and could lead to retention of carbon dioxide in the alveoli and blood stream. It should be mentioned as well that there is no reservoir bag in the system whereby properly managed, assisted or controlled respirations can be instituted.

(6) Nonrebreathing technic. The most recent method to be utilized in pediatric anesthesia incorporates a valvular arrangement in which all the exhaled gases are removed from the system, thus eliminating

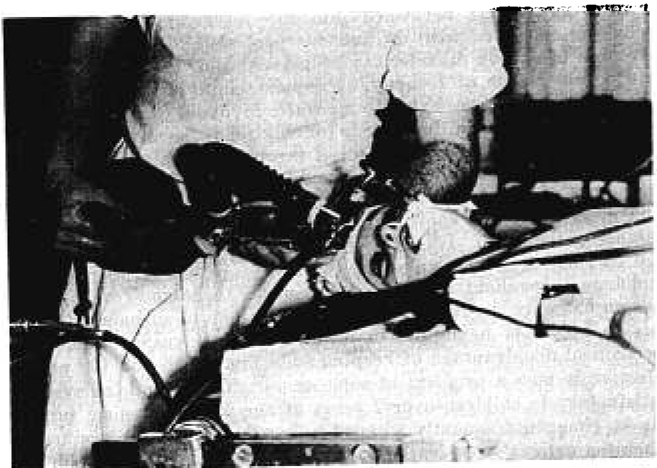

Fig. 3. To-and-fro absorption system with O'Shaughnessy by-pass to facilitate changing soda-lime canisters without losing anesthetic mixture. Assisted respirations are being employed.

the hazard of carbon dioxide accumulation by rebreathing, and obviating the necessity for soda lime. Several varieties of valves have been assessed, and the one using rubber flaps has been found to be the most efficient and least resistant (4, 5, 6, 7). When the word "valve" is used, resistance is brought to mind. With the rubber flaps used in the nonrebreathing valve (fig. 4), the resistance at a flow rate of 15 liters per minute has been shown to be only 1.75 cm. of water on the inspiratory side and 1.0 cm. water on the expiratory side. It has been employed in infants of 2 and 3 months of age for periods up to three hours in duration without any evidence of the development of fatigue

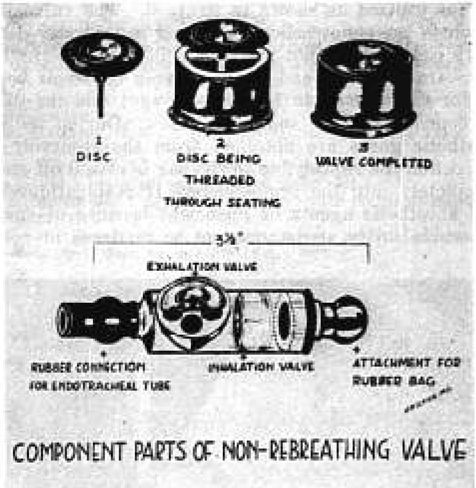

FIG. 4. Component parts of nonrebreathing valve. Rubber disks are fixed in central portion, which increases efficiency and decreases resistance.

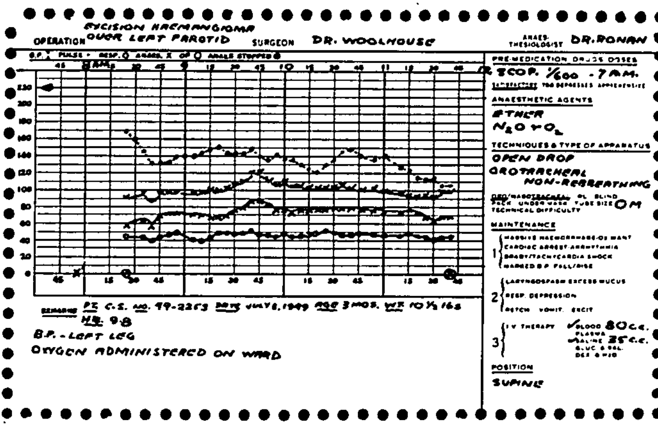

FIG. 5. Anesthetic record of 3 month old infant weighing 10½ pounds. Anesthesia for excision of hemangioma over left parotid area lasted three and one-half hours.

(fig. 5). It is utilized as shown in figure 6. The valve is placed in juxtaposition to the endotracheal tube, and in this way dead space is reduced to 9 cc., which is not more than is found in the mouth of a tiny infant. On the other end of the valve a reservoir bag is placed (2.5 liters for children up to 10 years of age) and the distal end of the bag is connected to the source of gases. During the inspiratory phase anesthetic gases are obtained from the reservoir bag, while during expiration the rubber flap to the bag is closed off and the gases escape completely into the atmosphere. If respirations become depressed by anesthetic agents or inefficient because of surgical entry into the thoracic cavity, assistance can be rendered or control estab-

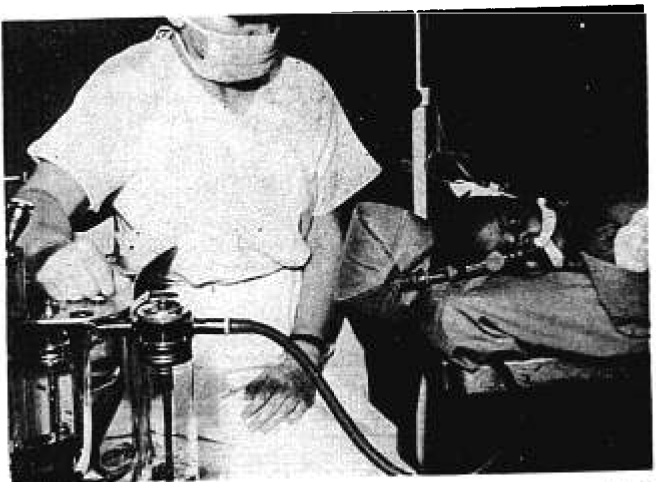

FIG. 6. The clinical application of the nonrebreathing valve is demonstrated. Note ether bottle on machine and the valve between the 2.5 liter reservoir bag and the plastic endotracheal tube.

lished without difficulty. With inspiration, the thumb of one hand is pressed over the exhalation valve while the bag is squeezed with the other hand. In the expiratory period, the thumb is removed from the exhalation valve, and the hand relaxed completely so the bag can refill from the machine. Small babies can be assisted in this way for hours. The agents most commonly employed with this technic are nitrous oxide, oxygen and ether. Of the various technics which have been enumerated, the nonrebreathing method is believed to satisfy best the demands made of the anesthetist in pediatric anesthesia.

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