DIFFICULTIES IN PAEDIATRIC ANAESTHESIA[1]

P. B. PERCHESON, M.D., F.R.C.P.(C), and JOHN J. CARROLL, M.D.[2]

PART I

GENERAL CONSIDERATIONS

IT IS A TRUISM that the extremes of life are the most hazardous periods of our existence. Of the two extremes, the infant or child presents the more incalculable and inscrutable physiologic variations to challenge the skill and ingenuity of the anaesthetist.

The relative dearth of research in this field (13) is understandable when we consider that in infants and children we are dealing with such rapidly changing physiologic states that separate studies at different ages are necessary. We are repeatedly faced with difficulty in establishing the borderline between normality and abnormality. More attention must, therefore, be focused on the development of normal standards for this period when homeostasis is either not yet developed or so easily upset.

The anaesthetist must deal with paediatric patients in countless circumstances where speculation and clinical experience must take the place of knowledge and established fact. The life and welfare of these patients depend very largely on the anaesthetist's ability to exercise instantaneous and accurate clinical judgment, a judgment which must be tempered by the fact that the smaller the patient the shorter the road to disaster

In order to minimize the difficulties in paediatric anaesthesia, it behooves us to acquire at least a working knowledge of the physiologic vacillations that the infant and child are likely to manifest. Consultation with the paediatrician and the internist is most desirable when perplexing electrolyte, fluid balance, circulatory, respiratory or metabolic upsets are present in the preoperative period. Moreover, the qualified paediatric surgeon (5) is probably better equipped to deal with the surgical problems of this age group Preoperative consultation and correction of physiologic upsets will protect the anaesthetist against many of the anaesthetic difficulties which may arise; because once the patient is anaesthetized, these difficulties do not permit recourse to laboratory findings, consultation with a colleague, or to the policy of watchful waiting—so common in the other specialties.

PHYSIOLOGICAL CONSIDERATIONS IN PAEDIATRIC ANAESTHESIA

Central Nervous System

The hypothalamic thermostat of the paediatric patient is unstable and has a tendency towards wide diurnal fluctuations. High temperatures increase the

[1]Department of Anaesthesia, Vancouver Grace and Burnaby General Hospitals, Vancouver British Columbia.

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basal metabolism rate which, in turn, increases the oxygen requirements, the pulse rate, and the respiratory rate. Under these conditions, additional fluid loss and electrolyte disturbances will rapidly ensue.

In the presence of fever, the convulsive threshold of the child is readily triggered; especially if fluid and electrolyte disturbances, hypoxia and carbon dioxide excess co-exist. Thus it is wise to reduce fever by permitting heat loss through perspiration. Simple expedients, such as removing heavy bed-covers, ensuring good ventilation of the operating rooms and providing tepid sponge-baths, are usually effectual if central nervous disease and bacterial infection are ruled out or treated. In some instances, the use of aspirin, alcohol sponges and specific therapy may be required. Adequate oxygenation and elimination of CO_2, treatment of dehydration, correction of calcium and other electrolyte disturbances, and the use of anti-convulsive drugs in the premedication are additional measures in the control and prevention of convulsions during anaesthesia.

Respiratory System

The respirations of the paediatric patient (13), especially of the newborn infant, are subject to very broad, so-called "normal" fluctuations. A rhythmically irregular respiratory pattern of the Cheyne-Stokes type is observed frequently in both the premature and the full-term infant. Body plethysmograph studies recorded an average rate of 58 per minute in the newborn, but the extent of the range was found to vary from 31 to 114. The tidal volume varies from 5 to 12 cc. in the premature infant and from 10 to 25 cc. in the full-term infant. Alveolar ventilation—a complex resulting from the depth, rate and shape of the respiratory curve—is impossible to determine, even approximately, in the infant. Little can be concluded from arithmetical averages wherein so much variation occurs, and it is therefore impossible to estimate conclusively the oxygen and carbon dioxide values in this age group.

A very significant fact (13) is that in both premature and full-term infants, periodic breathing can usually be changed to regular breathing by the administration of oxygen. Thus, it has been postulated that since the foetal and newborn respiratory pattern shows the same irregularity that is known to occur with oxygen lack, and since this irregularity is readily corrected by the administration of oxygen, there must exist in this age group a tissue lack of oxygen. This has been attributed (13) to the characteristics of the foetal type of haemoglobin, which, though fully saturated, does not give up oxygen to the tissues readily. The improvement of the infant in oxygen-enriched atmosphere is apparently due to the greater concentration of oxygen in physical solution in the plasma.

These considerations emphasize the importance of employing some form of oxygen-enriched anaesthesia in infants By the same token, some method of assisted ventilation which will increase the tidal volume from the normal 20 cc to 100 cc. (14) is indispensable We might therefore reiterate that high oxygen atmospheres and large tidal volumes are the sheet-anchors of paediatric anaesthesia. We must not forget that the technique employed must prevent CO_2 excess as this factor alone can cause sweating, tachycardia, rapid respirations, convulsions, and circulatory collapse.

Special Considerations of Ventilation and Circulation

Adequate ventilation and oxygenation are dependent upon good lung circulation. Both the blood volume and its distribution in the lungs and heart—the so-called lesser circulation—can be affected by many factors. Normally the latter amounts to about 20 to 30 per cent (4) of the total circulation. However, recent studies have demonstrated that approximately 80 per cent of the blood which pools in the legs when we assume the upright posture comes from the lungs and heart. Peripheral vasodilatation from anaesthetic drugs may effect a comparable redistribution. By the same token rapid blood loss may reduce the pulmonary blood volume by an amount equal to 50 per cent of the estimated blood loss Thus, factors such as dehydration, vasodilatation, blood loss, and unphysiological postures during anaesthesia, may decrease the volume of the lesser circulation to a greater extent than that of the systemic circulation. In this situation, the pulmonary blood volume may be decreased to the critical point of inadequate venous return to the heart. A tachycardia may not compensate for this inadequacy; therefore cardiac output can become critically reduced. This can only be prevented by the control or treatment of all the conditions which deplete the pulmonary blood volume to the critical level.

Furthermore, when the blood volume of the lesser circulation becomes critically depleted, the blood in the lungs may be distributed unevenly. In the lateral posture which may be required for surgery, not only the blood but also the alveolar (15) gases may be distributed unevenly throughout the lung tissue. In this situation, shallow ventilation may distribute a greater amount of oxygen to areas of the lung where the circulation is poor, and relatively smaller amounts of oxygen to the areas of good lung circulation. This paradoxical situation can be either improved or corrected with high oxygen concentrations combined with the large tidal volume of assisted or controlled ventilation.

The Cardiovascular System

The pulse rate varies from 160 in the infant to 120 in the child (20). The blood pressure varies from 70/30 in the infant to approximately 80/40 in the child. Haemoglobin values range from 18 gm. (13) at birth to about 12 gm. at the end of one year. Under anaesthesia pulse-rate variations from 100 to 200 are quite frequent.

It is a sign of good anaesthesia when the infant's pulse rate is below 130 and the child's below 110. This, of course, only holds true when relaxation is adequate and the colour, respirations and blood pressure are optimum. Circulatory collapse as evidenced by tachycardia or bradycardia, imperceptible pulse, pallor or cyanosis, and respiratory difficulties, should be considered as complications of anaesthesia. This is especially true when blood loss, adrenal insufficiency or surgical factors cannot be incriminated.

Fluid and Electrolyte Balance

Body water comprises about 70 per cent of the total body weight of the infant (16). It is postulated that in the infant the extracellular fluid volume comprises from 25 to 50 per cent of their total body water, as compared to 20 per cent in the adults. Thus, the adult whose extracellular fluid volume is about 14 litres ingests and excretes about 2 litres (equivalent to 1/7 of his extracellular fluid volume) daily. On the other hand, the infant whose extracellular fluid volume is about 2 litres ingests and excretes about 1 litre (equivalent to about ½ of its extracellular fluid volume) daily. It is obvious why deficits and abnormalities in fluid and electrolyte balance are at least seven times more likely to occur in the infant and child than in the adult.

Therefore the recognition and treatment of fluid and electrolyte deficits, when diarrhoea, vomiting, fever, trauma and decreased oral intake complicate the pre-operative period, are of paramount importance.

Some general principles in the approach to this problem are:

(*a*) Estimate the extent of dehydration that the disease process has inflicted on the child (1). This may be classified as mild, moderate or severe—amounting to 5, 10, or 15 per cent of body weight respectively—and will require the administration of proportionate amounts of oral or intravenous fluids. Approximately one-half of the quantity of fluids necessary to correct this existing dehydration is added to the maintenance requirements of the first day because this amount is sufficient to restore the extracellular (interstitial and plasma) fluid compartments.

(*b*) Where dehydration is mild to moderate, the total fluid requirements for the first day (the amount required to correct existing dehydration added to the 24-hour maintenance requirements) are administered over a 24-hour period. However, moderate to severe dehyration may necessitate more rapid rates of administration.

(*c*) When the child will tolerate it, oral administration of fluids is preferred and this can be continued until six hours before surgery.

(*d*) Blood, fluid and electrolyte losses from abdominal suction, etc., should be replaced as they occur.

(*e*) Shock should be treated with blood or plasma substitutes as indicated.

(*f*) After shock has been treated, it is safer to continue the intravenous with 5 per cent glucose or one-third normal saline in two-thirds 5 per cent glucose until clinical signs and laboratory data indicate the need of specific electrolytes in more concentrated solutions.

(*g*) Potassium solutions and sodium lactate should not be administered intravenously until shock is corrected and kidney function is re-established.

(*h*) An accurate fluid intake and output and weight chart should be kept and reviewed frequently (21).

In evaluating these patients, information must be obtained as regards recent diarrhoea, vomiting, excessive perspiration, fluid intake and output (1). A complete urinalysis and blood examination—including red cell count, haematocrit, N.P.N., sodium, potassium, chloride and CO_2 combining power—will help to elucidate the electrolyte and fluid deficits. Serum sodium can be estimated approximately be adding the figure 15 to the total of the serum chloride and the CO_2 combining power. All values must be in milliequivalents. It is well to remember that 10 per cent of body weight is equivalent to 15 per cent of body fluids.

Mild dehydration (1), as characterized by skin dryness, thirst and redness of the tongue and lips, usually indicates fluid deficit amounting to about 5 per cent of body weight. About 25 ml. per pound of body weight is required to correct this. However, as stated previously, only one-half of this amount is added to the maintenance fluid requirements as this is usually sufficient to replenish the extracellular fluid compartments. In these cases oral administration is preferred.

Moderate dehydration (1), as characterized by restlessness, irritability, sunken eye-balls and fontanelle, dryness of the lips and mouth, diminished skin turgor, cold extremities and an obviously ill patient, usually indicates fluid deficit amounting to 10 per cent of body weight—about 50 ml./lb. However, adequate replacement of extracellular fluids is accomplished by adding one-half of this amount to the maintenance requirements of the first day.

Severe dehydration (1) is characterized by a moribund infant. These patients are in shock and require immediate and adequate fluid therapy with blood, plasma substitutes or electrolyte solutions as indicated. A rapid rate of infusion (up to 15 ml./lb. in the first hour) may be required to raise and maintain their blood pressure. Their fluid deficit amounts to about 15 per cent of body weight or about 75 ml /lb. Although it may be necessary to replace only one-half of this, the volume of replacement is better judged by the clinical response of the patient.

Maintenance fluid requirements (1) to cover losses from urine and insensible perspiration, etc., will vary from 50 ml./lb. in the 5- to 20-lb. infant to about 30 ml./lb. in the 20- to 80-lb. child. Fever will increase these requirements by 8 per cent for each degree Fahrenheit that the temperature rises. Under normal circumstances, the maximal amount of fluid administered during surgery should not exceed 5 ml. lb. Even this amount may overload the 6- to 12-lb. age group. A vein should be cannulated in all infants requiring anything but the most minor surgery.

In the small infant whose 24-hour fluid requirements are about 300 ml., a two-way stop-cock should be incorporated into the intravenous set for the administration of anaesthetic drugs and medications during surgery. This will prevent cerebral or pulmonary oedema which might result if the drugs were otherwise injected into the intravenous tubing and the drip-rate necessarily increased to obtain their full effect.

The diagnosis of alkalosis or acidosis will depend on the correct interpretation of the history, character of the breathing, the urine and the blood pH (18). It is well to remember that the CO_2 combining power is an indirect measure of the blood pH. The true hydrogen ion concentration can be determined more accurately by measuring the alveolar CO_2 as this value corresponds to the tension of the carbon dioxide dissolved in the plasma.

Although the character of the breathing is our best clinical indicator of acidosis or alkalosis, one must not forget that a hyperpnoea of central origin may be compensated by the renal excretion of bicarbonate. In this situation, although the breathing is acidotic in character and the CO_2 combining power is low, the urine will be either neutral or alkaline and the arterial blood pH will be on the alkaline side, confirming the diagnosis of a compensated respiratory alkalosis rather than a metabolic acidosis.

Metabolic acidosis and alkalosis are usually associated with considerable fluid deficits (1). Alkalosis more often than acidosis is conductive to potassium and calcium deficits.

Mild acidosis may be corrected by the return of adequate kidney function, whereas, a CO_2 combining power below 12 milliequivalents associated with hyperpnoea will require the addition of appropriate amounts of one-sixth molar lactate solution as follows: 2 ml /lb. of body weight of one-sixth molar lactate will raise the CO_2 combining power by 1 mEq. Enough of this solution should be administered to raise the CO_2 combining power to 20 mEq (1). (The normal CO_2 combining power is 27.5 mEq or 55 volumes %.)

Alkalosis usually will be corrected by administration of normal saline. However, severe alkalosis with CO_2 values above 40 mEq., hypopnoea, cyanosis, abdominal distension and absence of bowel sounds may require the addition of potassium to effect clinical improvement. Potassium should not be given intravenously until an adequate flow of urine is established. It is a hazardous therapy unless abnormal losses have existed for 36 hours or more (1). The following formula is useful for estimating the therapeutic requirements: 1 mEq /lb. of body weight per 24 hours up to a total of 4 gm. (50 mEq) in a concentration not greater than 30 mEq /L.

Tetany will usually respond to intravenous calcium gluconate (1), 5 to 10 ml. of this solution diluted with normal saline to 40 ml. can be administered over a period of 10 minutes as often as required.

Basic considerations for calculating the fluid requirements of a fairly common group of pediatric problems are as follows:

(*a*) The infant with pyloric stenosis will require a repair solution of one-third normal saline in two-thirds 5 per cent glucose in quantities up to a total of 75 cc. per pound of body weight over a 24-hour period.

(*b*) The infant with intestinal obstruction will require the judicious administration of normal saline or Ringer's lactate solution. It is safer to limit normal saline to approximately one-third of the calculated fluid requirements and to use code 8 (one-third normal saline in two-thirds 5 per cent glucose) or 5 per cent glucose solution for the remainder (1).

(*c*) In lower intestinal losses, and fever states with excessive perspiration and decreased fluid intake, a safer procedure is to administer code 8 until kidney function improves and blood N.P N. starts to fall (1). After this, specific therapy for acidosis and potassium deficit can be considered. Shock may require blood or blood substitutes.

(*d*) As a general rule, saline should be used sparingly in the small infant (2 to 5 Kg.). Even code 8 contains about 4 times more saline than the infant's kidney can deal with normally.

Many serious situations can be avoided if at least a working knowledge of the fluid and electrolyte deficits of this age group is acquired. For instance, severe and prolonged lower intestinal losses, especially in the presence of fever and decreased oral intake, may result in dehydration, metabolic acidosis, potassium deficiency and poor kidney function. Improper therapy with normal saline per se will aggravate the condition and may precipitate convulsions Normal saline increases the plasma chloride relatively more than the plasma sodium and thus imposes the strain of a dilutional acidosis in one's attempt to correct an already established metabolic acidosis. If this infant is then subjected to anaesthesia wherein CO_2 excess is not prevented, a further insult is added in the form of a respiratory acidosis superimposed on a metabolic acidosis which was already aggravated by a dilutional acidosis. In this situation, circulatory collapse, cardiac arrest or convulsions are almost inevitable.

Likewise, the infant with pyloric stenosis may develop metabolic alkalosis wherein poor kidney function, chloride, potassium and calcium deficits may manifest themselves clinically by apathy, hypotonia, absence of bowel sounds, respiratory weakness and cyanosis. Incorrect fluid therapy, such as 5 per cent glucose exclusively, may help to correct the dehydration, but it does not restore the chloride, potassium and calcium deficits, and thus it aggravates the alkalosis.

Similarly, in this situation, anaesthesia and surgery are prone to precipitate disasters such as circulatory and respiratory collapse and convulsions. Several factors might contribute to this: hyperventilation during anaesthesia could aggravate the alkalosis and precipitate convulsions; potassium deficiency could increase the infant's susceptibility to tubo-curare; dehydration and under-nutrition might depress renal and liver functions and thus interfere with the detoxification and excretion of anaesthetic agents and succinylcholine-like relaxants.

Even if surgery proves to be uneventful, the continuing potassium losses in the postoperative period could precipitate weakness, apathy, intestinal ileus and circulatory collapse.

Therefore, we can avoid many serious difficulties in paediatric anaesthesia by concerning ourselves with the proper electrolyte and fluid therapy. Research in electrolyte and fluid balance is still in a state of dynamic darkness; therefore, paediatric consultation is not only desirable but often indispensable. In situations where consultation is unobtainable, the anaesthetist may be forced to deal with this problem in the preoperative preparation of these patients

Endocrine Factors

Adrenal insufficiency—characterized by dehydration, failure to gain weight, vomiting and frequently diaorrhea—has been described in the literature (19). Children with this condition have been restored to good health by the administration of salt, DOCA and cortical extracts. Without this therapy, anaesthesia and surgery could be especially dangerous for these patients.

Other infants and children have had the benefits of cortisone therapy for its anti-inflammatory, anti-allergic or anti-shock properties (12). Therefore, conditions such as dermatitis, eye inflammations, asthma, rheumatic fever, fulminating septicaemia or staphylococcal pneumonitis may have necessitated the administration of cortical extracts.

It is generally recognized that all cortical extracts depress the pituitary secretion of ACTH (9). This may cause prolonged adrenal cortical depression which could precipitate circulatory collapse during stress situations such as anaesthesia and surgery Since laboratory tests for adrenal cortical function may be equivocal, difficult to interpret, and often require several days to complete and assess, it is safer for us to assume that an infant or child who has been treated with cortical extracts in the past year is a potential victim of Addison's disease. They will require prophylactic cortisone administration before, during and after surgery. ACTH therapy is not as dependable as cortisone (9) because its use may take up to six days to restore adrenal cortical function. Even then, the anaesthetist cannot be certain that the adrenal cortex will respond adequately to the increased demands imposed upon it by surgery and anaesthesia. Without prophylactic steroid therapy, a shock-like picture may manifest itself before, during or after surgery Pallor with circulatory collapse which is refractory to treatment with pressor drugs and intravenous solutions is characteristic of this type of complication

In these patients, a history of previous steroid therapy plus laboratory evidence of hypoglycaemia, low blood sodium and chloride, high potassium values and a high total eosinophile count will establish the diagnosis of adrenal insufficiency (9). A poor response to pressor drugs and intravenous therapy should excite one's suspicions of this condition.

In the preparation of these patients for surgery, the intramuscular route of administration is preferred—even though the drug takes effect more slowly than when administered orally. The injection of cortisone or hydrocortisone assures us that the patient is getting the drug in the required amounts. A dose of 3 milligrams per pound of body weight is given—48 hours, 24 hours and 2 hours—before surgery. During surgery, intravenous hydrocortisone must be available for the treatment of any untoward event which might be attributed to an inadequate concentration of blood corticoids.

The large thymus as a cause of death under anaesthesia has been based on tradition rather than on fact (13). The more likely causes of death are overdosage of anaesthetic drugs, asphyxia and the lack of appreciation that the margin between good health and disaster is especially narrow in children.

PART II

Techniques in Paediatric Anaesthesia

Advances in most branches of anaesthesia have added new drugs and new techniques to our armamentarium. Many of these have been applied to the anaesthesia of infants and children with variable results. Difficulties in their application can only be overcome by devising equipment and methods of administration which are tolerated by the infant rather than subjecting this age group to machines and techniques which were devised for the adult. One often hears the sweeping statement that all of the methods and agents for anaesthesia can be used on the paediatric patient. This we believe to be true in principle but not in practice, because, as yet, advances in paediatric equipment and techniques have not kept pace with our enthusiasm to extend all of the modern concepts of anaesthesia to this age group. Thus the use of adult equipment in prolonged paediatric anaesthesia invariably leads to increased resistance, fatigue, and exhaustion of the respiratory system, CO_2 accumulation, sweating, fever, and circulatory collapse.

Open Ether with Oxygen

From the above deliberations it is not surprising that the technique of open drop ether with a flow of oxygen under the mask has been the workhorse not only of the occasional anaesthetist but also of many specialists. There is much to commend a technique where simplicity and minimal equipment prevail, and hypoxia can be avoided by the simple expedient of flowing 1 to 2 litres of oxygen under the mask (2).

However, there are many drawbacks with this technique:

(*a*) Prolonged surgery with this method tends to fatigue the infant whose inhalations must pass through several layers of gauze.

(*b*) The dead space under the mask which may amount to 50 to 100 ml. may result in the accumulation of CO_2.

(*c*) Minute to minute control of the unstable respiratory mechanism of the infant is not possible because the technique does not incorporate facilities for controlled or assisted respiration.

(*d*) In major abdominal surgery, control of relaxation is not always possible. Straining, cyanosis, tachycardia and increased secretions from anaesthesia which is too light will often give way to apnoea and circulatory collapse from anaesthesia which is too deep. This type of "see-saw" anaesthesia is exhausting not only to the patient but to the surgeon and anaesthetist as well.

(*e*) Prolonged administration of ether results in liver and kidney depression, haemoconcentration and increased incidence of postoperative depression and vomiting.

Despite these disadvantages, it is still satisfactory for short extra-abdominal operations in the relatively healthier infants and children. Divinyl ether (Vinethene) is considered safer than ethyl chloride for the induction of these patients (2).

In our quest for means to circumvent the drawbacks of open ether, many improvisations and techniques have been developed which attempt to supplement the art of anaesthesia with the more modern concept of balanced anaesthesia. This consists of administering small doses of several drugs for their specific and desirable effects. In addition, the horizons of paediatric surgery have widened considerably in the past few years and anaesthesia must cope with the increasing demands of this extending field. Therefore a short review of the advantages and disadvantages of the many other available anaesthetic techniques for paediatric surgery is in order.

Co_2 Absorption Technique

The standard closed-circuit machine is too cumbersome for infants and children because of the increased resistance and dead space. However, the introduction of the infant circle absorber has made closed-circuit anaesthesia feasible in this age group. It has placed cyclopropane at the disposal of the paediatric anaesthetist. The unit was devised with a view to eliminating dead space and respiratory resistance to the maximum degree. Although its efficiency for the newborn or very young infant may still be challenged, it has made safe closed-circuit anaesthesia available for the older infant and child.

The to-and-fro absorption technique was designed to fulfil the physiologic requirements of the infant and child. However, because of the tendency to overheating of the soda-lime canister there is a rise in body temperature, and the perspiration becomes profuse. This problem may persist despite frequent changes of soda-lime and canisters and the use of ice bags (2). One must remember that when the size of the canister greatly exceeds the child's tidal volume, the proximal soda-lime will exhaust rapidly and add considerably to the dead space. The unit is relatively cumbersome and its efficiency in the very young infant is questionable.

Semi-Closed or Partial-Rebreathing Technique

The semi-closed or partial-rebreathing technique owes its efficiency to the high flow of gases, part of which, along with a portion of the expirations, are blown off through the exhalation valve. By this means the CO_2 in the system is usually maintained near physiological levels. However, it has the following disadvantages: (*a*) Large volumes of gases must be employed uneconomically (2). (*b*) Efficient utilization of cyclopropane and ether is relatively impossible. (*c*) It is not suitable for operations requiring deeper planes of anaesthesia unless supplemented by curare or nerve blocks. When cyclopropane or ether is used in this technique, the large flow of gases into the non-closed system dilutes the effects of these stronger agents, and even control of the planes of anaesthesia becomes very difficult. Without the addition of nerve blocks or curare this method does not provide the surgeon with the smooth and adequate relaxation required for abdominal surgery. Thus there is a sequence of light anaesthesia with its straining, pulse variations and increased secretions, alternating with profound anaesthesia with its depression bordering on complete collapse. This "see-saw" anaesthesia embarrasses all concerned—patient, surgeon, and anaesthetist.

Combined To-and-Fro or Circle (2) *Absorption and Partial-Rebreathing Technique*

The partial-rebreathing aspect of this technique utilizes a moderate flow of gases with a blow-off adjustment either through the conventional expiratory valve or through the distal end of the reservoir bag where a paper clip (2) can be attached to regulate the amount of escape. This is combined with the to-and-fro or circle absorption apparatus in order to gain the advantages of both techniques. This may be more apparent than real, because the high flow of gases still tends to make control of anaesthesia more difficult, and the to-and-fro absorption technique still tends to cause overheating

The Insufflation Technique

The insufflation of ether and air into the infant's mouth is mentioned only to be condemned as unphysiological and exhausting. The method lacks control of both the drug concentration and the infant's respirations. The high flow may form a barrier to the spontaneous respiration and promote the accumulation of carbon dioxide.

A modification of this, known as the Ayre's technique, has been used to advantage for operations requiring little relaxation. The method is physiologically efficient because both the reservoir bag and the expiratory valve are discarded and the anaesthetic mixture is opened to the outside air. A flow of about two litres per minute enables the infant to inhale the anaesthetic mixture through one arm of the metal T-piece and outside air through the open-end arm The entire exhalation of the infant is discharged through the open arm of the T-piece. There is practically no resistence with this system and some form of assisted respiration can be carried out by plugging the open arm of the T-piece intermittently. However, the method is not suitable for deep anaesthesia and was originally devised by Ayre for cleft-lip operations on children.

The Non-Rebreathing Technique

This method incorporates a non-rebreathing valve of low resistance which removes all the exhaled gases from the system. The elimination of resistance and CO_2 accumulation has made this technique very useful for anaesthesia in the young infant. Assisted ventilation can be exercised by simultaneously squeezing the bag and plugging the valve with one's finger. The Fink modification of this valve automatically closes when the bag is squeezed. However, there are some disadvantages to the non-rebreathing technique. Induction must be accomplished by some other method (2) and intubation is essential for the adequate elimination of dead space. Furthermore, good relaxation is very difficult to achieve in the older infant and child. Therefore, "see-saw" anaesthesia is likely to prevail during abdominal surgery unless relaxants are injected intermittently.

Curare Techniques

The curare techniques in infants and children provide the anaesthetist with a medium for effecting and maintaining a minute to minute control of the respirations wherein the full tidal volumes of 100 cc. or more are utilized. In addition, the quantities of anaesthetic agents are reduced markedly and the relaxation provided facilitates the work of the surgeon. With this technique, endotracheal intubation, high oxygen concentrations and some method of assisting or controlling respirations are mandatory. All techniques which incorporate a source of oxygen and a rebreathing bag are suitable for curare administrtion. Thus "see-saw" anaesthesia can be avoided by the judicious administration of curare.

However, many authorities (5, 14) question the wisdom of injecting curare into infants and children. Stead (6) and Hodges (3) believe that the newborn infant tolerates tubo-curare poorly because it responds to the drug like a patient afflicted with myasthenia gravis. One hardly needs to be reminded of the profound and prolonged depression that tubo-curare inflicts on myasthenic patients. Conversely, suxamethonium, which is a bromide derivative of succinylcholine, appears to be well tolerated by the infant and child. Stead and Hodges reported that repeated administration of small dosages of suxamethonium—up to a total of 15 to 45 mg.—produced no incidence of prolonged apnoea in over 300 patients. They concluded that the infant tolerates suxamethonium at least twice as well as the adult, even though the infant's plasma cholinesterase level is comparatively lower. Stead used suxamethonium in dosages ranging from 0.3 to 0.8 mg./kg. of body weight and repeated these as often as required. Our experience with suxamethonium over the past four years has indicated that the drug can be both efficacious and relatively safe in children. We have used small quantities in infants and, to date, there have been no cases of prolonged apnoea or undue depression. However, we still view with trepidation repeated administrations of curare in the very young infant. Where clinical evidence of dehydration and electrolyte deficit is apparent, the drug may be dangerous and relaxation should be attempted by other methods. Although curare provides the anaesthetist with an effective means of controlling relaxation and ventilation, it does not block the autonomic reflexes. These may cause pulse-rate and circulatory disturbances which may prove deleterious to the infant.

Intubation Techniques

Endotracheal intubation is the *sine qua non* of good paediatric anaesthesia. It is indispensable to the proper utilization of the non-rebreathing, the Ayre's and all curare techniques. Even the more efficient methods of ether administration such as the Flagg's can draw-over technique require intubation. Intubation either contributes to or confers more efficiency to all paediatric techniques because it practically eliminates the large dead space which might otherwise be present in the face mask. It facilitates the control of the airway and the tidal volumes of the patient. Specifically, safer planes of anaesthesia can be maintained during abdominal surgery without the fear of precipitating laryngospasm, stridor, reflex apnoea or other respiratory aberrations. Though some may argue that the incidence of infant morbidity may be increased by the occasional trauma of intubation, we feel that the safety and control established by the tube is a major factor in lowering surgical mortality. Because intubation makes anaesthesia safer, more physiological, more controllable, more predictable and more reversible, the narrow road from apparent good health to disaster can be better charted in the intubated infant and child.

Block Anaesthesia

Block anaesthesia such as spinal, epidural and regional infiltration can be utilized to great advantage in infants and children. Difficulties in controlling the patient, establishing dosages and maintaining the height and duration of the block have probably resulted in lack of enthusiasm for these procedures. With regards to epidural block, it has been our experience that relatively larger dosages of anaesthetic agents, far beyond those suggested by the stature and body weight, are required in the paediatric patient. Hunter (8) refers to this problem in the administration of spinal anaesthesia to children. It seems that because of the highly vascular piamater, the drug is rapidly absorbed into the blood stream, leaving a smaller quantity to become fixed to the nerve roots. This tendency to rapid absorption probably prevails in the epidural space of infants and children.

Since spinal and epidural anaesthesia is next to impossible to execute in the uncooperative squirming child, we believe that these youngsters should be put to sleep prior to block administration. A vein should be cannulated if an intravenous drip is not already running. In this way, quiet and controllable conditions facilitate block procedures, whereas the intravenous serves as a safeguard against complications which might arise either during or after the block. In the toxic and dehydrated child, block anaesthesia may be hazardous unless pressor drugs, oxygen and intravenous therapy are used judiciously. Under these conditions it may be the anaesthetic of choice (11), because once the spinal or epidural is established "see-saw" anaesthesia is usually prevented. Pulse-rate, respiratory, temperature, electrolyte and fluid disturbances are better controlled by regional anaesthesia. Nitrous-oxide and oxygen mixtures are usually sufficient to keep the child asleep throughout an operation performed with block anaesthesia. Admittedly, block administration may be more difficult to execute than the surgical operation. However, under controlled conditions, the task is less tedious and the results rewarding to the patient, surgeon, and anaesthetist.

We have found that an infant will require at least 6 ml. of 1 per cent Xylocaine to effect an epidural block, while a 6- to 8-year-old child may require 8 to 12 ml. of 2 per cent Xylocaine for the same procedure. The addition of 1-2 mg. of neosynephrine to the aqueous Xylocaine tends to prolong the duration of the block and prevent undue drops in blood pressure. We deplore the use of Xylocaine-epinephrine solutions because epinephrine will increase the infant's pulse rate and will preclude the administration of cyclopropane or trichlorethylene if the block wears off too soon or proves inadequate. Also, there is some evidence (17) that because of the acid pH necessary to keep the epinephrine stable in the stock Xylocaine-epinephrine solutions, the mixture can release neurotoxic metallic ions from plated-metal syringes and receptacles.

Where spinal or epidural anaesthesia is not feasible, we believe that regional infiltration is a valuable adjunct to light inhalation anaesthesia.

Special Considerations in the Premedication of the Paediatric Patient

It is our contention that proper premedication of the paediatric patient is a variable factor which depends upon the technique and the agent that is to be used for anaesthesia When the technique does not routinely incorporate measures for assisting or controlling respirations, then minimal depressant drugs and maximal doses of drying agent are indicated. In comparable doses scopolamine is a better drying agent and longer lasting than atropine. Scopolamine has a central amnesic action which potentiates the hypnotic properties of opiates and barbiturates. Atropine, on the other hand, is a good drying agent when large doses are administered about one-half hour before the operation However, larger doses stimulate the central nervous system and thus increase metabolism and oxygen requirements We prefer either morphine or meperidine (Demerol) as preoperative sedatives in the older infant and child We have found that the phenothiazine drug promethazine (Phenergan of Poulenc Limited) has desirable preoperative properties. There is a growing body of authorities (7) who believe that the phenothiazine drugs exert their depressant action on the reticular activating system of the brain stem They consider these so-called reticular formations to be centres of prodigious synaptic activity where autonomic, sensory and motor impulses are collected and integrated before being relayed to the thalamus and cortex Penfield (10) has shown that the cortex merely acts as a way-station for sensory impulses which arise in the periphery and converge on the brain stem Likewise, the cortex merely acts as a way-station for motor impulses which are integrated in the reticular formations and destined to reach the muscles through the cortico-spinal tracts. He demonstrated that pain pathways leaving the brain stem make no detour to the cortex but pass directly to the thalamus and back again through the reticular formations. Because destruction of the upper regions of the brain stem produces somnolence and unconsciousness, the state of arousal and consciousness is apparently the result of reticular formation activity and its effect upon the cortex. Thus we concur with Penfield, who maintains that the main target of premedication should be this rendezvous of psyche and soma—the reticular formations—and not the cortex. To accomplish this, we use promethazine in doses of approximately 1 mg. for every 3 lbs. of body weight. This has resulted in effecting a more quiescent and tranquil patient in whom induction of anaesthesia is facilitated, and maintenance is accomplished with weaker and less toxic anaesthetic mixtures. Promethazine offers many other advantages (7) in paediatric premedication: (*a*) It depresses vagal and sympathetic reflexes and thus stabilizes the cardiovascular system. (*b*) It helps to protect the respiratory system against reflex disturbances such as may occur during abdominal surgery. (*c*) It potentiates the drying effect of atropine and scopolamine (*d*) It has appreciable anti-emetic, anti-convulsive and anti-pyretic properties. (*e*) It has no appreciable effort on blood pressure and does not depress respiration. All of these factors are most desirable targets to aim for in the paediatric patient.

Our premedication routine consists of giving only scopolamine and promethazine to infants weighing less than 20 lb. Scopolamine is used in doses varying from 0.1 mg. in the smaller infants to 0.14 mg. in those weighing 20 lb., and promethazine is administered in doses of 1 mg. for every 3 lb. of body weight. In children weighing more than 20 lb., Demerol to the extent of 0.5 mg./lb. or morphine to the extent of 0.5 mg. to 0.7 mg. for every 10 lb. of body weight, is added to the prescribed dosages of scopolamine and promethazine. Therefore, a 30-lb. child may receive 0.15 mg. of scopolamine (gr. 1/400) plus 10 mg. of promethazine and either 2.0 mg. of morphine or 15.0 mg. of Demerol. The amounts of Demerol and morphine are reduced by about 25 per cent when the open-ether technique is contemplated.

Induction of the Paediatric Patient

The hazards of vomiting, silent regurgitation and air-swallowing can be practically eliminated by passing a gastric tube in all infants before the induction of anaesthesia. Since crying practically doubles the metabolism and oxygen requirements (13), and wakefulness without crying causes a 15 per cent increase in these factors, it is certainly of great benefit to the child if a smooth and rapid induction is carried out. We believe that the addition of promethazine to the premedication has facilitated the induction appreciably. Some of us prefer rapid intravenous induction with thiopentone in dosages of 2 mg./lb. combined with 15 to 20 mg. of the cation of suxamethonium. Thiopentone and suxamethonium are miscible without precipitation and can be administered from one syringe. In the 2- to 5-year-old child, suxamethonium in dosages of less than 15 to 20 mg. may not relax the glottis sufficiently to permit intubation. Therefore, 15 to 20 mg. of relaxant is used routinely in this age group. Under the age of 2 years, the veins may be more difficult to cannulate, therefore, cyclopropane induction is usually preferred. However, if an intravenous is already established, suxamethonium is administered in dosages from ¼ to ½ mg./lb. For this reason, all the patients who are induced with the thiopentone-suxamethonium technique and most of the patients who are induced with cyclopropane are intubated.

Maintenance of Anaesthesia

For most of the extra-peritoneal surgery, including tonsillectomies, we prefer nitrous oxide plus oxygen and trichlorethylene mixtures in a semi-closed or non-rebreathing system. This mixture is non-explosive and permits the use of cautery and X-ray during surgery. For some of the short fracture procedures the further addition of curare or thiopentene may be required occasionally. For abdominal surgery, some of us prefer block procedures in conjunction with a light inhalational anaesthetic. Others use either cyclopropane in an infant CO_2 absorption system, or a non-rebreathing ether technique with small supplements of curare.

Summary and Conclusions

The most serious difficulties in paediatric anaesthesia may not be directly related to the agents, techniques and abilities of the anaesthetist, as the sick child may be debilitated by electrolyte and fluid deficits of such magnitude that respiratory and circulatory collapse will occur even in the best of hands. More time, attention and care must be given to the clinical evaluation and correction of these factors in order to prevent disaster. It may take up to 24 hours to properly and adequately correct dehydration, acid-base disturbances, potassium loss, and calcium deficits. In these situations the paediatrician may be indispensable. The anaesthetist must have at least a working knowledge of these problems in order to be able to cope with them adequately in situations where paediatric or internist consultation is not available.

When electrolyte and fluid deficits have been corrected, difficulties can be better avoided by choosing methods, agents and anaesthetic techniques which are least disturbing to the labile respiratory, circulatory, metabolic and temperature regulating systems of the infant and child. In this respect, premedication must aim not only at reducing secretions, metabolism and oxygen requirements, but also at achieving a tranquil co-operative patient in whom vagal, sympathetic, motor and sensory pathways have been centrally obtunded. Likewise, maintenance of anaesthesia should incorporate versatility to the extent of permitting adequate oxygen, control of respiration, and, sufficient relaxation without undue circulatory and respiratory depression. We believe that the use of phenothiazine drugs in the premedication, and the administration of "controlled" blocks for the maintenance of anaesthesia may help to solve some of these difficulties.

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Résumé

En anesthésie pédiâtrique, les plus sérieuses difficultés peuvent bien ne pas être d'ordre technique ou ne pas être attribuables aux agents ou à la dextérité de l'anesthésiste, si le petit malade est dans un tel déséquilibre hydrique et électrolytique qu'un collapse respiratoire et circulatoire peut survenir même dans les mains les plus habiles. Pour éviter un désastre, l'évaluation clinique et la correction de ces facteurs requièrent plus de temps, d'attention et de soin. Pour corriger adéquatement la déshydratation, le déséquilibre acidebase, les pertes de potassium

et le déficit de calcium, il peut être nécessaire de prendre 24 heures. Dans de telles circonstances, le pédiâtre peut devenir indispensable. L'anesthésiste doit être assez familier avec ces problèmes pour pouvoir, s'il est impossible de consulter un pédiâtre ou un interniste, prendre la situation en main et permettre l'intervention.

Une fois l'équilibre hydrique et électrolytique rétabli, il sera plus facile de contourner les difficultés inhérentes au choix des méthodes, des agents et des techniques anesthésiques qui affecteront le moins les systèmes régulateurs labiles de la respiration, de la circulation, de la température et du métabolisme de l'enfant ou du poupon. A ce sujet, la prémédication ne doit pas viser qu'à réduire les sécrétions, abaisser le métabolisme et diminuer les besoins d'oxygène, mais elle doit tendre également à présenter à la salle d'opération un malade calme, coopérant dont l'activité nerveuse est ralentie, activité vagale, sympathique, sensitivo-sensorielle et motrice. Il en est ainsi du maintien de l'anesthésie: il doit être possible de faire des variations qui permettent une oxygénation adéquate, un contrôle de la respiration et un relâchement musculaire suffisant tout en évitant une dépression respiratoire et circulatoire nuisible. Nous avons la conviction que l'emploi des dérivés de la phénothiazine dans la prémédication et la pratique de blocages circonscrits pour le maintien de l'anesthésie peuvent aider à résoudre quelques-unes de ces difficultés.

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