MODERN ASPECTS OF THE MANAGEMENT OF THE NEWBORN UNDERGOING OPERATION

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The principles of neonatal anaesthesia have been described by a number of eminent paediatric anaesthesiologists (Rees, 1958; Smith, 1959; Wilton and Wilson, 1965; Stead and Nightingale, 1969). Since then important advances have been made in the preparation of the infant for surgery, in the increased use of ventilator therapy, in the better understanding of fluid, electrolyte and metabolic disturbances and in the use of improved equipment and therapeutic agents, all of which have contributed to lowering the mortality and morbidity of neonatal surgery. The purpose of this paper is to describe some of these recent advances and to re-emphasize some of the important aspects of neonatal anaesthesia.

TRANSPORTATION

Despite the recognition, more than 10 years ago, that a properly equipped and experienced team should be available to transport the ill neonate to the regional neonatal centre (Eckstein and Glover, 1964), it is only in recent years that this concept has gained worldwide acceptance (Blake et al., 1975; Dangel, 1975a; Hackel, 1975). The importance of a transport system lies in the fact that it encourages early treatment to correct acidosis, hypoxia, hypoglycaemia, hypo-volaemia and hypothermia, and to protect the airway and guarantee adequate pulmonary ventilation. The baby can therefore be transported in an optimum condition, which must inevitably influence mortality and morbidity, since it reduces the duration of physiological decompensation which, if prolonged, becomes progressively more difficult to reverse.

Blake and colleagues (1975) describe the transport system, of newborn infants suffering from the respiratory distress syndrome, to their hospital for intensive care from a radius of 50 miles. Of 222 infants transported in this manner, 40% were thought to improve during the journey, 56% remained stable and only 4% appeared to deteriorate. There was no correlation between the distance travelled and the survival rate.

PREPARATION BEFORE OPERATION

A nasogastric tube should be passed in all cases (Bush, 1971a), except in babies with oesophageal atresia, and the gastric secretions allowed to drain freely. The amount lost should be measured so that adequate replacement may be given i.v.

An i.v. infusion should be established so that appropriate fluids may be given throughout the operative period. The range of equipment now available enables percutaneous techniques to be used for almost all venepunctures, and cutdown techniques need only rarely be used. Dangel (1975b) has outlined the various routes that may be used, including scalp veins, peripheral veins using a needle or plastic cannula, central venous catheterization via the jugular,
subclavian or femoral veins and umbilical vein cannulation.

Central nervous system depressants and analgesics derived from the morphine alkaloids are more toxic to the newborn, because of the immaturity of the enzymatic systems involved in their metabolism (Mirkin, 1975) and should not be given before operation.

Atropine is seldom required because vagal tone is low in the newborn and, particularly in babies with viscid secretions resulting from dehydration or mucoviscidosis, may precipitate plugging of bronchioles or even bronchi with inspissated mucus. Gillick (1974) described a baby who developed opisthotonus, seizures, periodic breathing, dilated pupils and dry skin following a total dose of 0.1 mg/kg of atropine sulphate given over a period of 5 h.

Vitamin K 1 mg should be given i.m. because of the immaturity of the hepatic enzyme systems in producing prothrombin.

The baby should only be brought to theatre in an incubator when the body temperature is greater than 35 °C, adequate hydration and blood volume have been achieved, and all the necessary preparations and investigations performed.

ANAESTHETIC APPARATUS

Fisk (1973) has reviewed the systems for inhalation anaesthesia for children and has stressed the value of the Rees modification of Ayre's T-piece. This system is undoubtedly the most appropriate for neonatal anaesthesia using a fresh gas flow of 3 litre/min (Nightingale, Richards and Glass, 1965). A small heat moisture exchanger may be used if humidification of anaesthetic gases is required and is simple to use and safe, cheap and reasonably effective.

The heart rate and pulmonary ventilation may be monitored with an oesophageal stethoscope (except in babies with oesophageal atresia). Arterial pressure may now be measured accurately and non-invasively using an ultrasonic transducer and sphygmomanometer cuff (Poppers, 1973). In rare instances the arterial pressure may be measured directly using an i.a. cannula either in the temporal artery (Gauderer and Holgersen, 1974) or in the radial artery (Furman, Hairabet and Roman, 1972). The advantage of this technique is that repeated arterial blood sampling may be performed. A technique for obtaining repeated arterial blood samples from peripheral arteries without an indwelling cannula has been described by Wunderlich and Reynolds (1972).

Blood loss on swabs is most conveniently measured colorimetrically (Rickham, 1954) and the loss by suction by the use of a calibrated cylinder (Lowe and Levin, 1970) which may be placed in the sucker bottle.

The operating theatre should be kept warm (25 °C) and the patient placed on some warming device (Taylor, 1961; Nesling, 1963; Lewis, Shaw and Etchells, 1973), the safest of which is the water blanket thermostatically controlled to 37 °C. The baby is covered with a layer of gamgee and a sheet of plastic (Vidrape) which completely covers the infant and prevents heat loss. Whenever a warming device is used, the central body temperature must be monitored using an oesophageal or rectal probe. Using this method it has not been found necessary to use any system for heating and humidifying the inspired gases as advocated by some anaesthetists to help maintain body temperature (Rashad and Benson, 1967; Voss, personal communication).

ANAESTHETIC AGENTS

The most commonly used anaesthetic agent would appear to be halothane. However, this agent is not without risk in the newborn infant. Wilton and Wilson (1965) noted that "cardiac and circulatory depression have been seen to occur when halothane is used in a concentration sufficient to attain relaxation in the neonatal patient". This observation may in part be explained by the relative centralization of the circulatory system with peripheral vasoconstriction so that any drug causing vasodilatation will tend to cause circulatory depression. The observation by Gregory, Eger and Munson (1969) that the MAC for halothane in the neonate is nearly 40% greater than in adults has obvious relevance in this context.

There is no doubt that 70% nitrous oxide in oxygen with controlled ventilation is a highly satisfactory anaesthetic agent in neonatal anaesthesia, and supplementation is unnecessary.

NEUROMUSCULAR BLOCKING AGENTS

The work of Stead (1955) and Bush and Stead (1962) showed that the newborn infant in the first few days of life was more sensitive to tubocurarine than the adult and that this sensitivity gradually diminished over the first 14 days of extra-uterine life. Using similar criteria, Bush (1964) showed that the newborn was also sensitive to alcuronium.

However, using surface area to calculate dose requirements, Walts and Dillon (1969) suggested that the sensitivity of the newborn could not be demonstrated. If, however, body weight was used to determine dose, then a myasthenic response to tubocurarine could be shown.
Sabawala (1970) verified the increased sensitivity to antidepolarizing drugs in excised neonatal intercostal muscle and suggested that this response may be accounted for by the immaturity of the developing neuromuscular junction. However, the ten-fold sensitivity demonstrated by these in vitro experiments is not found in clinical practice.

An attempt to assess the role of plasma protein concentrations in the newborn in determining tubocurarine requirements (Vivori, Bush and Ireland, 1974) showed that there was no correlation between the concentration of plasma protein fractions and tubocurarine requirements. Furthermore, in those infants who required two operations within the neonatal period of life, there was no correlation between the concentration of gamma globulin and the tubocurarine requirements. Whilst this study rules out the possibility that quantitative changes in plasma protein concentration would account for the observed changes in sensitivity to tubocurarine, it does not exclude any qualitative changes in binding.

Bennett and his co-workers (1975) showed that the neonate is sensitive to pancuronium and that, furthermore, the potency compared with tubocurarine is more marked at birth (1 : 9) and diminishes to 1 : 6 at 28 days of life. They suggest that pancuronium may be given in the following doses: 0–1 week, 30 μg/kg; 1–2 weeks, 60 μg/kg, 2–4 weeks, 90 μg/kg. These doses should be reduced in prematurity, acidosis, hypothermia and in the presence of certain antibiotics and other anaesthetic agents.

Doubt on the validity of the assumption that the newborn is sensitive to antidepolarizing drugs has recently been expressed by Goudsouzian and his colleagues (1975) as a result of measuring the thumb adduction in response to supramaximal single shock ulnar nerve stimulation. The effective dose of tubocurarine to produce a 90% block in infants under 10 days was 0.34 mg/kg, which was not statistically different from infants of all other age groups. However, infants less than 10 days old exhibited the widest variation of response. Gestational age was considered not to be a factor to account for this wide spread of dose requirements. The rate of recovery was also similar in all age groups studied. These results await confirmation in a larger group of patients.

It should be noted, however, that the dose of 0.34 mg/kg of tubocurarine is very similar to that found by Bush and Stead (1962) in this age group and, in view of this, perhaps the study by Goudsouzian and his colleagues (1975) could be interpreted as demonstrating the increased sensitivity of infants and children to tubocurarine rather than the lack of sensitivity of the newborn infant.

Bennett and his co-workers (1976) have recently shown that tubocurarine can be given in a bolus injection of 250 μg/kg in the first 7 days of life, 400 μg/kg from the 7th to the 14th day and 500 μg/kg between the 14th and 28th day of life. The usual caveat to reduce these doses in the presence of prematurity, acidosis, hypothermia and potent anaesthetics is still valid. These dose schedules may be useful when intubation and controlled ventilation are not instituted before induction of anaesthesia. However, endotracheal intubation and initiation of controlled ventilation, before the administration of muscle relaxants, allows titration of the requirements, thus avoiding the difficulties of overdosage.

It is generally agreed that the response of the newborn to the depolarizing muscle relaxant suxamethonium differs only marginally from its effect in the adult, and is in marked contrast to the increased sensitivity to antidepolarizing drugs. Prolonged apnoea in the newborn infant with atypical pseudocholinesterase born to a homozygous atypical mother receiving suxamethonium before Caesarean section has been described recently (Baraka et al., 1975).

Providing the relaxant drugs were carefully titrated against the infant's requirements during induction and maintenance of anaesthesia, thus avoiding overdosage, these drugs have been used with safety and with satisfactory results in many hundreds of neonatal surgical procedures. The importance of titration to reach the required dose for each patient is essential if an overdose is to be avoided, especially in view of the findings of the wide variation of response of the newborn infant less than 10 days old (Goudsouzian et al., 1975), and because of the effect of other physical and chemical agents (for example, metabolic disturbances, halothane) that may potentiate the effect of these drugs.

In the full-term infant, once control of the airway is achieved, tubocurarine 0.5 mg should be administered i.v. Subsequent doses of 0.25 mg or 0.125 mg should be given to achieve adequate relaxation and full control of pulmonary ventilation. In the pre-term infant an initial dose of 0.25 mg should be used. The initial dose of pancuronium should be 0.1 mg in the full-term infant and 0.05 mg in the premature, with subsequent doses of 0.05 mg and 0.025 mg. Incremental doses during operation should be one-tenth of the total initial dose. Suxamethonium 1.5 mg/kg in a suitable dilution may be given to all newborn infants, providing a suitable dose of atropine has
been given previously and a dibucaine number less than 20 is not suspected. Because most neonatal surgical operations last in excess of 30 min and in view of the known tendency for the neonate to develop a phase II block, suxamethonium should be used only for those operations likely to last less than 20 min.

The neuromuscular blocking action of anti-depolarizing drugs must always be reversed at the end of operation using atropine 0.02 mg/kg and neostigmine 0.08 mg/kg, but at least 40 min from the time of the relaxant administration must elapse before these drugs are given. Inadequate reversal results from actual overdosage, or relative overdosage caused by potentiation resulting from a variety of agents. A low ionized calcium concentration is frequently found in the newborn, particularly following the administration of citrated blood and, in view of the role of calcium in the release of acetylcholine at the pre-junctional membrane, inadequate reversal may be countered by the i.v. administration of calcium gluconate 10% in a dose of 15 mg/kg.

**FLUID THERAPY**

The approach to fluid therapy has undergone a considerable change over the last decade, largely as a result of alterations in attitude to fluid requirements following observations made in adults undergoing surgery and also a more scientific appraisal of the available data in the newborn infant. This topic was the subject of recent reviews (Bush, 1971b; Young, 1973).

Bennett (1975) has specifically described fluid balance in the newborn, and hydration of the low birth weight infant has been comprehensively discussed by Roy and Sinclair (1975). This complex subject can only be accurately interpreted if adequate information is available. Hence, it is vital that as many measurements are made as possible so that a comprehensive picture can be developed. The state of hydration may be assessed by clinical examination of the baby, observing such features as skin turgor, fontanelle fullness, vein filling and arterial pressure. Estimation of haemoglobin, haematocrit, serum and urine electrolyte values, osmolality and volume of urine produced also assist in determining the electrolyte deficiency or excess, as well as the degree of hydration. Major electrolytic problems and dehydration are not common in most neonates presenting for surgery unless the diagnosis has been considerably delayed and loss of fluid has occurred either by vomiting or by secretion into the dilated bowel proximal to the site of an intestinal obstruction. Long-standing pyloric stenosis may produce severe disturbances, which should be corrected before surgery is undertaken, even though 24–48 h may be required.

Administration during operation must be based on the normal maintenance requirements (50 ml/kg, 24 h⁻¹ on the 1st day, increasing to 100 ml/kg, 24 h⁻¹ by the 3rd day of life) (paradoxically, the low birth weight infant requires 25% more fluid) together with an estimate of fluid translocated at the site of operation (1–5 ml/kg, h⁻¹). Unless there has been some considerable deficit before operation, the fluid should be given as 5% dextrose in half-strength Hartmann's solution. In the presence of a low albumin concentration (<30 g/dl) plasma protein fraction up to 30 ml/kg may be given i.v.

In the presence of a high haematocrit (>70%) low molecular weight dextran may have beneficial rheological effects, but the dose must not exceed 15 ml/kg in order to avoid the unwanted side-effects. Rheomacrodex has been advocated in the treatment of necrotizing enterocolitis, to improve the blood supply to the damaged bowel in the hope of increasing bowel survival (Krasna et al., 1973).

Fluid and electrolyte requirements after operation must include the daily maintenance requirement together with any abnormal losses from the gastrointestinal tract, and increased insensible loss if the newborn is being treated in a radiant heat cradle or undergoing phototherapy, or in the presence of fever. The value of estimating urinary osmolality to determine the water requirements has been documented by Coran, Das and Eraklis (1971). Daily serum electrolytes should be performed using micro methods whenever fluid and electrolytes have to be administered i.v.

**BLOOD VOLUME**

The initial blood volume of the neonate will be greatly influenced by factors at the time of delivery. Thus Sisson, Knutson and Kendall (1973) found that, in infants born by Caesarean section, immediate clamping of the umbilical cord produced a mean blood volume of 87 ml/kg, whereas if clamping was delayed for 3 min the blood volume was 67 ml/kg in infants held 15 cm above the level of the uterus and 106 ml/kg in infants held 15 cm below. Following readjustment after birth, Bennett (1975) has suggested that if the plasma volume of the newborn is accepted as 50 ml/kg, the blood volume may be calculated using the formula (50+haematocrit) ml/kg. During
operation, colloid solution either as plasma protein
to fraction or as whole blood, depending on the infant's
haematocrit, should be used when the blood volume
loss exceeds 10% of the calculated blood volume.

INTUBATION

The vital necessity for safeguarding the airway and
the need for control of pulmonary ventilation during
operation implies than an artificial airway should
always be instituted. In the majority of instances, an
endotracheal tube can be passed, although in the
presence of certain lesions, for example tracheal
agenesis (Lyons and Bruce, 1968), severe subglottic
stenosis (O'Kane, 1936) or laryngeal web (Hannahalla
and Rosales, 1975), a tracheostomy is necessary.

Endotracheal intubation should be performed
before the induction of anaesthesia if this is indicated
on clinical grounds. The following factors should be
considered; the ease with whichatraumatic intubation
can be achieved, the possible presence of conditions
making intubation difficult or impossible, the difficulty
which may be experienced in maintaining the airway
with a facepiece, the presence of intestinal obstruction
and the poor general condition of the patient. If, on
the other hand, the patient is in excellent condition,
cries lustily indicating absence of congenital abnor-
malities in the larynx, exhibits strong muscular move-
ments makingatraumatic intubation impossible, and
an airway can be guaranteed with a facepiece, then
intubation should be performed under optimal
conditions following induction of anaesthesia.

The most common condition making intubation
difficult or impossible is congenital cartilaginous sub-
glottic stenosis (Sayre and Hall, 1954) which is often
associated with congenital oesophageal atresia and
tracheo-oesophageal fistula.

Because of the difficulties in visualizing the laryn-
geal opening following insertion of the blade of the
laryngoscope in the vallecula, it is necessary, in the
newborn infant, to lift the epiglottis forward by
passing the tip of the blade into the aditus of the
larynx. This manoeuvre is best achieved by inserting
a straight-bladed laryngoscope into the opening of the
oesophagus and then gently withdrawing the blade at
the same time exerting a backward pressure on the
larynx from the anterior aspect of the neck. Great
gentleness and precision are required.

Plain red rubber or Portex tubes should be used
and the size inserted should comfortably fit in the
subglottic region. In most cases the 2.5-mm i.d. tube
will be required in the infant less than 2 kg, the 3-mm
i.d. in the 2-3.5 kg and the 3.5-mm i.d. in the infant
more than 3.5 kg in weight. Endotracheal tubes of
varying diameters are not recommended because it is
impossible to eliminate damage to the cricoid region
and if left for any length of time, the tube may cause
dilatation of the larynx (Brandstater, 1969). Salem
and colleagues (1973) suggest that the insertion of a
long endotracheal tube below the site of the tracheo-
oesophageal fistula will eliminate gastric distension
following the institution of IPPV. However, this
manoeuvre will not always be successful unless the
endotracheal tube fits the diameter of the trachea
with the risk of damage at the level of the cricoid and
also because, as the authors point out, the fistula is
sometimes to be found at the carina or in the main
bronchi.

PULMONARY VENTILATION

Pulmonary ventilation of the newborn may be
jeopardized by a congenital pre-existing abnormality,
such as diaphragmatic hernia, pulmonary cysts
(Buntain et al., 1974), abdominal distension caused
by intestinal obstruction or soiling of the tracheo-
bronchial tree in the presence of a tracheo-oesophageal
fistula. Following birth, inadequate surfactant pro-
duction leading to hyaline membrane disease,
meconium aspiration or apnoeic attacks may cause
further respiratory insufficiency. During operation,
particularly if the site is intrathoracic or abdominal,
further respiratory embarrassment can readily be
caused by adverse positioning on the table, surgical
retraction and the effects of anaesthetic agents. It is
now suspected that, particularly in the newborn
infant, the closing volume of the lungs is present
during normal tidal breathing (Mansell, Bryan and
Levison, 1972). The need to maintain a normal FRC
is vital, therefore, if progressive atelectasis and
shunting from the right side to the left side of the
heart with the subsequent decrease in arterial Po2 is
to be prevented. There can be no doubt that con-
trolled pulmonary ventilation with PEEP of 5 cm
H2O must be used in all infants undergoing surgery.

It has been suggested (Gray and Edwards, 1948)
that in the presence of an emphysematous cyst of the
lung, because of the possibility of rupture of the cyst
or distortion of the rest of the tracheobronchial tree,
controlled pulmonary ventilation should not be in-
tituted until the bronchus can be clamped. Spon-
taneous respiration in the lateral chest position, with
an open chest and the depressant effects of anaes-
thetic agents, make this technique too hazardous in
the newborn. Contrary to expectation, gentle full
control of pulmonary ventilation using adequate doses
of relaxant drugs in these circumstances is well tolerated and does not produce the consequences predicted. One-lung anaesthesia, which is technically difficult and not without other problems, is also not necessary.

Distension of the stomach in infants with a congenital tracheo-oesophageal fistula may, if severe, cause respiratory embarrassment (Baraka and Slim, 1970). However, if full doses of antidepolarizing relaxants are used and pulmonary ventilation gently controlled, distension of the stomach does not occur. Indeed, it is exceedingly rare to find excessive gastric distension in a baby with a tracheo-oesophageal fistula before operation unless respiratory distress with a low pulmonary compliance is present. This finding suggests that using intratracheal pressures of the same order during IPPV as those used by the baby during spontaneous respiration will not produce gastric distension. Although there will be an inevitable leak of gases through the fistula from the trachea into the stomach during inspiration, which will return during expiration, this tidal flow of gases will only cause an increased deadspace effect which must therefore be taken into account when the tidal volume is being considered. Providing gases can pass freely both ways through the fistula, excessive build-up will not occur. Gastric distension may be produced, however, when halothane is being employed initially when chest wall spasm, leading to a lowered compliance of the chest vis à vis the abdomen, allows preferential flow of gas into the stomach. Rees’ (1958) belief that the risk of gastric distension is preferable to those likely to accrue without controlled ventilation is still valid.

Recent advances in bronchoscopy technique now enable a pliable catheter to be inserted through the fistula from the trachea and left in situ, thus permitting venting of the stomach and assisting the surgeon in locating the fistula.

MANAGEMENT AFTER OPERATION

Great advances have been made in the postoperative management of the newborn not only in the prevention and treatment of respiratory failure (Bush, 1969; Stocks, 1973), metabolic disturbances and i.v. feeding (Baum and Aynsley-Green, 1975; Ghadini, 1975) but also in the general care of the newborn (Klaus and Fanaroff, 1973). Increased knowledge in these areas of responsibility has undoubtedly been largely instrumental for the improved survival of newborn infants undergoing surgery.

REFERENCES


