SURGERY IN THE NEWBORN*

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(*Continued from the issue of the* Journal *for 13 August, p. 695*)

4. Operation

(*a*) *Timing*

With all neonatal anomalies it is axiomatic that the sooner the operation is performed the better.[6]

The most urgent emergencies are the diaphragmatic hernias, where a delay of even 5 minutes may make all the difference between success and failure. It is our policy to take these infants directly to the theatre on their arrival at the hospital, because past experience has shown that even the few extra minutes spent in taking them to the wards have been responsible for fatalities.

In large omphaloceles the urgency is almost as great, especially if previous rupture of the sac has taken place.

In babies suffering from intestinal obstruction relief of the obstruction is the primary consideration.[63] These cases are urgent because the increasing abdominal distension causes impairment of diaphragmatic excursion, limitation of respiratory exchange, dyspnoea, anoxia, and exhaustion. However, some time is profitably spent in rehydrating the infant and in decompressing the gastro-intestinal tract. In general a delay of a few hours is justifiable, except in cases where volvulus is suspected.[63]

In cases of oesophageal atresia there is less urgency, provided adequate precautions are taken against aspiration of secretions and vomitus.[63] Indeed, 12 hours spent in preparing the infant for surgery and controlling infection are often to the advantage of the patient. The same holds for rectal agenesis, although the period of preparation should not exceed 6 - 12 hours.

(*b*) *Anaesthesia*

Expert anaesthesia is probably the greatest single factor responsible for the reduction in the mortality of neonatal surgical emergencies within recent years.[4,34,55,59] Without it surgery in the newborn should not be undertaken.

The technique of paediatric anaesthesia cannot be discussed in this paper, but certain collateral factors which also concern the anaesthetist are important, including control of body temperature, maintenance of blood volume and tracheo-bronchial toilet:

(i) *Body temperature.* It has been noticed that small infants stand operation much better, are less easily shocked, and are more resistant to anoxia if the body temperature is lowered.[53] A drop in temperature to approximately 90°F has often greatly facilitated anaesthesia and post-operative recovery.[53] However, temperatures below this level, particularly in premature infants, may be injurious and predispose to sclerema. Anaesthesia depresses and renders inefficient the temperature-regulating mechanism of the body and may lead to an excessive rise or fall in body temperature.[65] Air-conditioning of operating theatres is now widely accepted as the logical solution to regulation of body temperature during anaesthesia. In our theatres, however, which are air-conditioned with an average temperature range of 70° - 75°F and a relative humidity of 70 - 75%, there is a progressive drop in body temperature with time, the mean drop in temperature in neonates being 5·9°F.[65]

Fig. 14. Swabs 10″ × 14″, 2 layers of muslin. With experience it may be possible to assess the blood loss from the extent of staining of the swabs.

Fig. 14A. Scale for weighing used swabs to determine the amount of blood loss.

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We therefore protect the infant's arms, legs, lateral abdominal wall, and upper chest, with cotton wool and place a well-wrapped hot-water bottle at 101°F under him. This reduces the mean fall to 3·2°F.[65]

(ii) *Blood volume.* During all surgical procedures body water is lost at variable rates in respiration, sweating, and evaporation from the wound. In long operations it is therefore necessary to provide intravenous fluids in the form of 5% dextrose in water at a rate of 5 ml. per lb. per hour.[59] This may be increased if there is excessive sweating. Replacement of blood loss is the most important problem in the operating theatre.[49,59,62] Although infants have a very high haemoglobin concentration at birth, blood loss during operation must be meticulously replaced; it should be remembered that the loss

TABLE III. BLOOD LOSS DURING NEONATAL SURGERY

Anomaly	*Absolute Loss (ml.)*	*% of Blood Volume*
Oesophageal atresia	35	14
Diaphragmatic hernia	25	10
Intestinal atresia	60	25
Rectal agenesis	60	25
Omphalocele	35	13

of 40 ml. of blood in a 5 lb. baby is equal to the loss of 1 litre in an adult.[49] The blood must be replaced volume for volume as it is being lost, and the only accurate method of assessing blood loss is to weigh swabs before and after use (Fig. 14a). (With experience visual estimation of blood on the swabs can be fairly accurate and is of use when dry swabs cannot be used—Fig. 14.) Average amounts of blood lost for various operations on our cases are given in Table III. Replacement is made directly into the intravenous needle (previously set up) by injecting from a syringe 5 - 10 ml. at a time at the rate of 5 ml. per minute. This is greatly facilitated by the use of a 3-way stopcock attached to the intravenous drip (Fig. 15).

(iii) *Tracheobronchial toilet.* At the completion of the operation tracheobronchial suction should be performed through the endotracheal tube. After ensuring that the pharynx is clear of secretions the endotracheal tube is removed. Great pains should be taken to ensure that the mouth and pharynx are clear of secretions at the end of anaesthesia. In addition, the stomach should be carefully emptied by suction applied to the nasogastric tube (which was passed pre-operatively). There should be no hesitation in performing bronchoscopy if these methods fail to clear the air passages adequately, or if there is evidence of persistent atelectasis or respiratory distress.

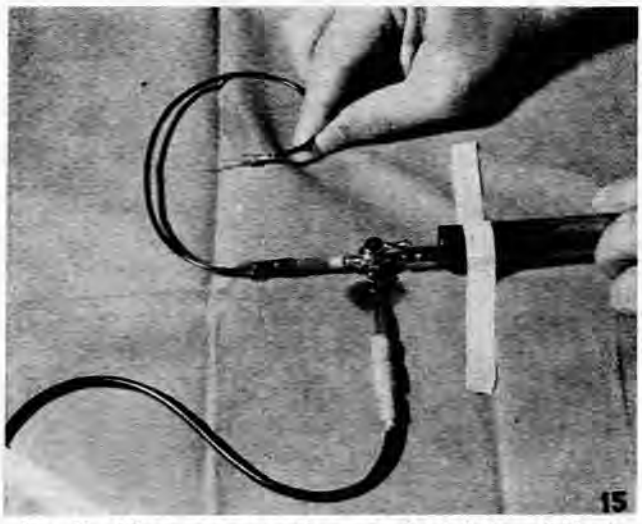

Fig. 15. Three-way connection used for infusion of blood during the operation.

(c) *Surgical Technique*

This can be acquired only by a system of apprenticeship and experience. Denis Browne has aptly remarked that 'the average competent general surgeon will have no greater success with neonatal bowel obstruction than he would have with brain tumours',[7] and Willis Potts asks, 'Is it quite fair that a surgeon who would not think of operating on a brain tumour or repairing a cleft palate should tackle a case of atresia of the rectum in a male infant with a rectovesical fistula, when he never before has seen such a case nor witnessed the operative repair?'[46]

It is not merely new and specialized techniques that have to be learnt, but rather the fineness of the technique and gentleness in handling the delicate tissues as well as familarity with the numerous variations of particular congenital defects that may occur. The surgeon must know how to reduce blood loss to an absolute minimum, and how to judge accurately the amount that has been lost. He must be capable of precision work when suturing the minute bowel, and he must develop a special skill in the dissection of small structures and in their accurate reconstruction. A great deal more could be said about the various surgical procedures themselves, and about the numerous practical hints which make for perfection;[46,50] suffice it to say that unless there are contra-indications such as prematurity, multiple malformations, respiratory complications, or infection, infants tolerate one operation of moderate length very well, provided the defect is fully corrected.

The surgeon who makes the first effort to correct a deformity has the unique opportunity of producing the most acceptable and lasting result. Repeated anaesthetics without adequate intervals between them and partially corrective surgical procedures are often doomed to failure.

A concerted effort should therefore be made to carry out the definitive procedure at the time of the first operation. This is always necessary in cases with diaphragmatic hernia or intestinal obstruction. In oesophageal atresia we prefer primary repair of the defect, but in babies weighing less than 4½ lb. it is safer to do a preliminary oesophagotomy and gastrostomy followed by secondary oesophagoplasty at the age of 3 - 6 months. Large omphaloceles must usually be repaired immediately, but in very small premature infants they may be treated conservatively (by applying 2% mercurochrome daily for 3 days and allowing the sac to shrink and become epithelized). In rectal agenesis many surgeons prefer immediate abdominoperineal reconstruction. In babies weighing less than 4½ lb., however, and in neglected cases, a preliminary colostomy followed by secondary reconstruction at a later date is safer.

Whatever the procedure, meticulous attention to detail is of paramount importance. Special attention should be paid to closure of the wound. Bulky dressings, encircling bandages, and adhesive plaster, all of which interfere with respiration, must be avoided. The wound can be adequately covered with water-tight collodion or nobecutane applied over a thin strip of gauze.

Particular care must be exercised in transferring the baby from the operating table back to the incubator, especially when underwater drains, etc. have been inserted. This is often the most critical phase of the infant's illness, yet at this moment, especially after a long and tedious operation, vigilance is apt to relax. This has led to many catastrophes in the past; chest drains have been pulled out, intravenous needles have been dislodged, bottles of blood have been dropped, infants have suddenly vomited and died of suffocation, etc.[47] The surgeon should therefore stand by until the baby is safely on his way to the recovery room, properly attended.

5. Post-operative Care

(a) Constant Vigilance

The need for keeping a close watch on the infant is even greater in the post-operative than the pre-operative period.[4] The child must be nursed in a fully equipped recovery room or neonatal surgical unit.[13,37,51,53,62] Round-the-clock 'specialling' by a senior registrar as well as by a competent nurse is essential. Recovery-room nurses must be specially trained to watch for the earliest signs of respiratory obstruction, laboured or shallow respiration, silent regurgitation, and circulatory collapse. Careful charts must be kept with recordings of temperature, pulse, respirations, fluid balance etc. On occasion we have even used a cardiac monitor.

The surgeon himself must accept his full responsibility, viz. the total care of the patient. He should visit the infant frequently (at least 4 times a day) to evaluate progress and check the treatment. He should supervise not only the initial intensive care, but also the later feeding regime; attend to complications such as pneumonia, gastro-enteritis, etc., and the hundred-and-one items which make infant care so exacting, yet fascinating.

A paediatrician should be constantly available in the more dignified position of super-consultant, just like the pathologist, radiologist and all other members of the team. In this way he can be of greater help than would be the case if he were asked to accept responsibilities of post-operative care with which he finds himself unfamiliar, and which he is not qualified to accept.

The remarks made under the heading 'adequate pre-operative management' in regard to minimal interference, isolation and control of environment, prevention of suffocation, gastro-intestinal decompression, hydration, blood transfusion, antibiotics, etc., are even more important in the post-operative care of these infants. Some of the more important factors which apply particularly to post-operative care require further elaboration.

(b) Care of the Respiratory System

Suffocation caused by aspiration of pharyngeal secretions or vomitus during the immediate post-operative period is without question the commonest cause of death in newborn infants submitted to surgery.[24,47] In a previous review I reported that 'aspiration pneumonia' was present in one-third of all the cases that died, and that in many others there was evidence of atelectasis or other respiratory complications.[32] Weakened infants, whether operated on or not, are liable to vomit, aspirate, and choke to death. This risk is greatly increased when there is a depressed cough reflex after anaesthesia. Very often such aspiration occurs with dramatic suddenness—an infant who has been doing well may be dead 5 minutes later. Constant attention to the respiratory system and measures directed at the prevention of inhalation of foreign material should therefore be regarded as the first priority in the care of these patients. We have constantly available an emergency respiratory set, consisting of laryngoscope, endotracheal tubes, infant bronchoscope, airways and tubing (Fig. 16) which is taken to the bedside of every small baby that has been operated upon.

Fig. 16. Respiratory emergency kit (see text).

Infants who tend to vomit should be nursed on their side in 20° to 30° of Trendelenburg position and turned from side to side at intervals, unless they are very weak or premature.[62] A suction apparatus and emergency kit must be in readiness for the immediate removal of secretions or vomitus which may collect in the pharynx. During the first 24 - 48 hours, the pharynx must be cleared at frequent intervals ($\frac{1}{2}$ - 1 hour) by an experienced nurse or registrar.

An infant's laryngoscope with endotracheal tubes (0 - 00 Magill Portex) and special small bronchoscopes must be kept beside the incubator for use in emergencies.[9] (Routine or frequent laryngoscopy for tracheobronchial toilet is not recommended because of the dangers of trauma.)

When there are signs of pulmonary complications an atmosphere very rich in oxygen (60 - 80%) may be necessary. In addition, the humidity should be increased up to 100% if possible—this has been said to be the greatest single factor in preventing pneumonia,[53] but there is a limit to the degree to which environmental humidity can be raised without causing hyperpyrexia.[63]

Tracheotomy may be necessary in certain cases with respiratory distress. It is important to realize that this should be done *early*; that is to say, when it is first thought of and not as a last desperate measure to save the exhausted infant. Often, in retrospect, one wonders why tracheotomy was delayed so long.[47]

(c) Intravenous Fluid Therapy

It is in the administration of post-operative fluids to newborn infants that most mistakes have been made in the past. Even today considerable confusion about the appropriate therapy still exists in the minds of paediatricians and surgeons, and metabolic studies on the response of newborn infants to trauma have provided conflicting results.[11,21,52-54,63] It is therefore best in the first place to consider certain general principles of treatment. Briefly, these are as follows:

(i) Each patient must be considered individually, and no rule of thumb can be formulated for the infant who has undergone a major surgical procedure.[10]

(ii) Requirements of the infant are conditioned by basic needs, the pre-operative condition, the events during surgery, and abnormal post-operative losses.[11,18,62,63]

(iii) Therapy should be directed at 'preventing the patient from becoming moist'.[11] This entails the following: (α) Accurate assessment of the total fluid requirements for the day;[1,15,34,62,63] (β) ordering not more than half the day's requirements at a time;[1,15,34] (γ) specifying the rate of infusion in ml. per hour and drops per minute (1 ml.=10 drops);[34] and (δ) ensuring that the infusion bottle contains not more than an amount equal to 10 ml. per lb. of the infant's weight (so that even rapid administration of the entire contents would not be fatal).[1,34]

(iv) Prevention of electrolyte imbalance and water intoxication by the judicious alternation of the various solutions required. This avoids the administration of large quantities of a single solution at one time. Excessive quantities of hypotonic solutions are particularly dangerous.[11,63,64]

(v) The fluid status must be checked by frequent clinical observation supplemented by appropriate laboratory tests if necessary.[1,18,34,62,63] Fluid and electrolyte calculations are no more than estimates and should, therefore, not be applied without being evaluated in the light of several daily clinical observations.[1] These include temperature, weight, intake and output record, and urine examination.

The subject of 'intravenous fluid therapy' (*c*) is continued under the headings (*d*), (*e*) and (*f*) now following:

(*d*) *Basic Requirements* (*Table IV*)

The newborn infant has excess body water, rapid fluid turnover, limited renal function, low plasma proteins and potassium, and high serum sodium and chlorides.[18,30] Many of these factors increase the danger of fluid overloading. Decreased bicarbonate and buffer activity set the stage for the second threat—that of acidosis.[30]

TABLE IV. DAILY MAINTENANCE REQUIREMENTS FOR NEWBORN INFANTS

	Amount per lb.	*Salt per lb.*	*Solutions per lb.*
Sodium	0·85 mEq.	50 mg. NaCl	5 ml. normal saline* or 7 ml. Darrow's solution*
Potassium	0·9 mEq.	70 mg. KCl	0·35 ml. 20% KCl†
Calcium	0·1 mEq.	20 mg. Cal gluconate	0·2 ml. 10% Ca gluconate
Protein	0·25 - 0·5 g.	—	5 ml. plasma‡ or 10 ml. travamin
Water	30 - 60 ml.	—	About 25 - 55 ml. 5% dextrose in water

* Preferably given as half-strength solutions (7 ml. Darrow's solution contains 20 mg. KCl).

† This must be diluted 80 times and the amount reduced to 0·25 ml. per lb. if Darrow's solution is used to provide sodium.

‡ The sodium content is equal to that in the same volume of normal saline (the sodium content of low-sodium travamin is negligible).

(i) WATER

At birth the body fluids of the infant constitute a larger proportion of body weight than in later life, and during the first 3 - 4 days of life losses by insensible routes and urine usually exceed intake.[30] The newborn infant tolerates such restricted intake very well.[1,63] Moreover, although the neonatal kidney can deal with basic amounts of water, urinary excretion during the 2nd and 3rd days of life is reduced and an excessive water load cannot be excreted.[63]

Comparatively small quantities of fluids are therefore required e.g. 30 ml. per lb. on the 1st day, 45 ml. per lb. on the 2nd day, and 60 ml. per lb. on the 3rd. The common belief that babies need 2½ oz. (80 ml.) per lb. per day does not apply to neonates, and in prematures the daily amount should be limited to 25 - 30 ml. per lb.[19,62,63]

Very soon, however, the water exchange in relation to body weight becomes 4 - 5 times as great as that of the adult.[58] This is mainly because the infant's body surface is relatively large, and insensible losses in proportion to body weight are therefore much greater than at any other period of life.[58,62] With this rapid turnover of fluid, therefore, the stage is set for dangerous and sudden departures either on the side of over-hydration or on that of dehydration. The former has been repeatedly emphasized, especially in connection with premature infants, and Gross[19] goes so far as to say, 'More babies have died of over-hydration than have died of dehydration; it is essential to realize that fluid therapy is important in saving life, but if overdone can rapidly produce a fatality'.

The great fear of drowning these babies has led to the practice of keeping infants 'on the dry side'.[19,52,53,62,63] In this, the pendulum has swung too far, because dehydration cannot be dismissed as completely harmless and may well result in a dangerous rise in the concentration of serum electrolytes and blood urea. It is now well recognized that the relatively immature kidney of a newborn infant shows a diminished capacity for conserving water. Although perfectly capable of diluting the urine, it fails to concentrate it. Furthermore, dehydration leads to a more rapid and a greater deterioration of renal function in the newborn than in older subjects.[61] Adequate amounts of fluid to relieve dehydration must therefore be given.

Additional mistakes have been made because infants have been regarded as miniature adults and accordingly expected to show the same retention of water after trauma. Recent work has clearly shown that the volume of urine passed by a newborn infant after surgery is equal to that of normal infants or even greater, that is to say, the newborn's kidney is unable to conserve water post-operatively.[10] However, if the operation is performed within 2 - 3 days of birth the urine volume may remain low for several days longer than the usual 3 or 4 days.[12,36]

In view of this we try to 'prevent the infant from becoming moist' by giving the usual maintenance requirements of fluid post-operatively. This amounts to 1,000 - 1,500 ml. per square metre per day, or 30 - 60 ml. per lb. per day.[10] If the infant is operated upon within the first 4 days of life we give 30 ml. per lb. on the day of the operation, 45 ml. per lb. on the 1st post-operative day and 60 ml. per lb. thereafter. These amounts, however, are adjusted according to the infant's needs as determined by repeated clinical examination and measurement of the urinary output.

(ii) ELECTROLYTES

Because of his inability to concentrate urine effectively, the newborn infant has to 'wash out' waste products with relatively large quantities of water.[63] In addition, the renal clearances of sodium, potassium, chloride and urea are always low, even when plasma concentrations are raised.[63] The danger of excess saline or potassium administration is therefore obvious.[54]

On the other hand, although excretion of these ions is restricted in the newborn, it is not negligible and often continues unaltered despite changes in the state of hydration, concentration of the urine, and extrarenal losses.[10]

Recent metabolic studies have shown that there is no reduction in the urinary excretion of sodium chloride after surgery.[10] The neonatal kidney appears to be unable to conserve these ions even when there are large extrarenal losses.[10,11] Salt depletion will result if saline is withheld for 2 - 3 days. Post-operatively the infant must therefore be provided with his maintenance requirements of sodium chloride, viz. about 50 mg. per lb. per day[59] (5 ml. of normal saline or 7 ml. of Darrow's solution per lb. per day). This amount should not be exceeded because of the danger of salt retention (which is increased if solutions of sodium salts without potassium are given[64]). On the other hand, lesser quantities may lead to serious hyponatraemia, and it is our practice to withhold sodium chloride on the day of the operation only.

Post-operative losses of potassium in the urine are increased, but excessive excretion is not maintained.[10] Although a small potassium deficit can usually be ignored because daily losses in the urine are small and soon corrected when the infant begins to take oral feeds,[11] prolonged deprivation of potassium may lead to serious hypokalaemia. This applies particularly to infants with intestinal obstruction who have become dehydrated and therefore depleted of potassium, because their bowel function is slow to recover after operation, and while ileus persists further losses increase the deficit.[64] It is therefore necessary to give the ordinary maintenance requirements of potassium post-operatively, i.e. 70 mg. per lb. per day (0·35 ml. of 20% potassium chloride per lb. per day). Newborn infants can excrete potassium freely[64]

but the intravenous administration of potassium immediately after operation may be dangerous because the concentration of potassium in the serum tends to rise precipitously if there is oliguria and if shock or anoxia occurs. It is our practice to give no potassium on the day of the operation, and to limit the amount on the 1st post-operative day to that contained in the Darrow's solution given to provide sodium chloride (i.e. 7 ml. of Darrow's per lb. per day, which contains 20 mg. of potassium chloride). Furthermore, when potassium is given intravenously its concentration should not exceed 35 mEq. per litre (i.e. 2·5 g. KCl per litre or a 0·25% solution of KCl).[63] If a 20% solution is being used, it must therefore be diluted at least 80 times. The rate of infusion must also be adjusted and should not exceed 27 mEq. of potassium (2 g. KCl) in 4 hours.[63]

It should not be forgotten that calcium and magnesium are both liable to be depleted by the same circumstances as lead to the loss of potassium and that the activity of calcium in extracellular fluid is diminished in alkalosis.[63] Sometimes intravenous calcium gluconate produces a striking response in patients with ileus.[63] Calcium should therefore be given post-operatively, especially if there are additional extrarenal fluid losses. The dose for infants is 20 mg. per lb. per day or 0·2 ml. of 10% calcium gluconate per lb. per day.[59]

(iii) CALORIES AND PROTEIN

An adequate supply of calories and proteins cannot be provided intravenously. It is therefore most desirable to resume oral feeding as soon as possible. A newborn infant requires 30 calories per lb. per day, and much more after operation. A 5% solution of dextrose in water (0·2 calories per ml.) can do no more than take the edge off starvation; 10% dextrose (0·4 calories per ml.) is liable to give rise to thrombophlebitis, and the routine use of ethyl alcohol (6 calories per ml.) is not justified in small infants. Fat emulsion (1·35 calories per ml.) is the best source of calories for intravenous use; up to 60 ml. of the emulsion per day appears to be metabolized satisfactorily by infants.[63]

Daily protein requirements amount to 0·5 g. per lb. Post-operatively there is an increase in nitrogen excretion[10] and up to 1·0 g. per lb. per day may be required to maintain nutrition. Unfortunately, intravenous plasma and protein hydrolysates are not of much value as sources of protein unless covered by an adequate quantity of non-protein calories.[63] Nevertheless, depleted protein stores may be partially replaced by infusion of these substances[63] and amounts of 10 ml. per lb. per day (0·5 g. of protein per lb. per day) are recommended.[59] Plasma tends to block the intravenous needle and it should therefore be given diluted to half or quarter strength.[64] It has the additional disadvantages that it contains 140 mEq. of sodium per litre. Amounts which provide sufficient protein will therefore result in an overload of sodium. Travamin is less effective than plasma[63] but it contains only negligible amounts of sodium (10 mEq. per litre) and potassium (20 mEq. per litre).

(iv) VITAMINS

Vitamins should be administered in adequate quantities during the post-operative period. This applies particularly to vitamins B and C which should be given in doses of 10 mg. of ascorbic acid per lb. per day and 1 ml. of vitamin-B complex per day throughout the period of parenteral therapy.[59]

(e) Rehydration and Replacement Requirements

(i) *Rehydration.* The fluid losses of moderately or severely dehydrated infants requiring urgent surgery cannot be entirely replenished pre-operatively.[20] Usually time will only permit the pre-operative replacement of half the deficit, and water conservation will continue post-operatively. The balance of the deficit should therefore be added to the maintenance requirements for the first 24 hours after operation. This balance is usually given in the form of half-strength Darrow's solution, but plain 5% dextrose in water or half-strength saline may be required, according to the pre-operative circumstances.[20]

(ii) *Replacement.* Replacement of fluids and electrolytes lost by vomiting, nasogastric suction, drainage tubes, ileostomy, etc., is obviously essential. Failure to replace may result in profound sodium or potassium depletion and acidosis.[63] Accurate measurement and charting of all abnormal losses is therefore obligatory (Fig. 17) and as a rule the losses are satisfactorily replaced with an equal volume of Darrow's solution.[20] When, however, losses are excessive, blood-chemistry studies and analysis of the fluid lost become necessary to act as guides to the type of replacement fluid to be given. Gross[19] has summed up the problem of intravenous fluid therapy most aptly in his statement: 'No problem encountered in the care of infants can be more perplexing at times than the determination of electrolyte requirements and the management of these in ways that are safe'. It is always difficult to decide how much water, minerals, protein and calories to give each infant during the neonatal period when the margins between enough and too much or too little are so small.[63] A clearly defined plan of treatment (Table V) is very necessary, but it is always wiser to prescribe the fluids

Fig. 17. Careful intake and output records of all surgical cases are kept.

TABLE V. GUIDE TO POST-OPERATIVE FLUID THERAPY IN NEWBORN INFANTS

	Maintenance Fluid	*Replacement Fluid*
Day of Operation	30 ml. per lb. 5% dextrose in water *only*	Darrow's solution equal to measured extra-renal losses
Day + 1	45 ml. per lb. Darrow's solution 7 ml. per lb; 10% Ca gluconate 0·2 ml. per lb; 5% dextrose in water—balance	ditto
Day + 2	60 ml. per lb. Darrow's solution 7 ml. per lb; 10% Ca gluconate 0·2 ml. per lb; 20% KCl 0·25 ml. per lb; 5% dextrose in water—balance	ditto
Day + 3 and onwards	60 ml. per lb. As on 2nd day, but using plasma 5 ml. per lb. or travamin 10 ml. per lb. instead of Darrow's on alternate days	ditto Also check serum electrolytes and carbon dioxide

N.B. On day of operation the remaining half of the estimated pre-operative deficit (if any) is also given as half-strength Darrow's solution.

for 8 or 12 hours rather than for a whole day,[36] and it is essential to check the fluid status several times a day by clinical observation, review of the intake and output charts, attention to the urinary output, and weight and laboratory tests if necessary. Our fluid calculations are regarded as no more than estimates and are never applied without repeated re-evaluation.

(*f*) *Blood Transfusion*

Provided blood loss has been meticulously replaced during the operation there is seldom any need for post-operative blood.[62] However, the haemoglobin concentration should be carefully watched; it should not be allowed to drop below 14·8 g.%.[18,53] Repeated small transfusions of 30 - 60 ml. of blood are often of great benefit. (Note that whole blood contains 70 mEq. of sodium per litre.)

Blood is preferably given as a single intravenous injection, by means of a syringe, in amounts not exceeding 10 ml. per lb., injected over a period of 15 - 30 minutes. A slow drip may be employed in non-urgent cases at a rate not exceeding 60 ml. per hour (10 drops per minute).[20]

(*g*) *Treatment of Distension, Ileus and Obstruction*

Marked abdominal distension usually accompanies intestinal obstruction, and occasionally it occurs with tracheo-oesophageal fistula. Some post-operative distension is common after abdominal operations, and if an anastomosis has been performed there is often temporary post-operative obstruction at the stoma. If there has been bacterial contamination of the peritoneum, and where gross biochemical shifts have occurred, paralytic ileus develops, which aggravates the abdominal distension.

Distension interferes with diaphragmatic movement and increases the risk of inhalation of vomitus. In addition, the danger of leakage from an anastomosis is increased, and there is interference with the return of normal intestinal tone and activity. The longer a state of ileus persists, the longer it takes to resume oral feeds and the greater is the risk of biochemical disturbance. Gastro-intestinal decompression is therefore very necessary.

Miller-Abbot and Cantor tubes are not practical. We use an infant-sized nasogastric plastic tube or a urethral catheter (number 8 - 12) with several holes cut in the part that rests in the stomach (Fig. 11). This is connected to a low-pressure suction apparatus and, further, is aspirated by syringe at frequent intervals. Unfortunately, a catheter of sufficient calibre to effect adequate decompression is liable to irritate the hypopharynx and epiglottis, producing oedema and introducing the danger of laryngeal obstruction. We therefore prefer not to leave the catheter *in situ* for long periods; it is our practice to leave it in the stomach from the time of admission until about 24 hours after operation. It is then removed and re-inserted every 3 - 4 hours according to the volume of the aspirate.

There is no objection to giving the infant small sips of glucose water or Darrow's solution at intervals to maintain patency of the tube and to keep the mouth clean.[47,62] The tube should also be irrigated every 2 hours with 5 - 10 ml. of Darrow's solution to prevent plugging — if fluid cannot be withdrawn the tube is probably kinked and must be readjusted.[62]

A method of avoiding the pharyngeal irritation caused by indwelling tubes is to perform a temporary gastrostomy, and apply suction drainage of this.[14] We have used this method with great success in an infant suffering from duodenal obstruction.[33] Gross[19] and others strongly recommend routine gastrostomy immediately after repair of oesophageal atresia, and through this the stomach is kept deflated for 24 - 36 hours after operation.

Decompression should be continued until abdominal distension abates, until normal bowel sounds return, and *until green material is no longer being aspirated.*[47] Throughout, charts of intake and output must be carefully kept.

Other measures which help to alleviate distension include the administration of oxygen in high concentration (90%), and (but only after normal peristalsis has returned) gentle dilation of the minute and collapsed colon by small saline enemas 2 - 3 times daily. Drugs like pitressin and prostigmin should not be used.

(*h*) *Feeding*

The sooner the infant can be fed by mouth the more rapidly will any chemical imbalance be corrected and wasted protein be replaced but, if oral feeding is commenced before the gastro-intestinal tract has fully recovered its tone, dangerous gastric dilatation or paralytic ileus may be precipitated. There is often a severe degree of mechanical obstruction for 2 - 3 days after gastro-enterostomy or intestinal anastomosis in infants. In such cases oral feeding will only aggravate distension and increase the risk of leakage from the suture line. Feeds are therefore started as soon as, but not before, the gastric aspirate is free from bile.

When anastomosis has been performed, oral feeds may have to be withheld for several days. A tube may be passed through the anastomosis into the distal bowel for the purpose of post-operative feeding. This tube should be brought out through a gastrostomy to obviate the risk of pharyngeal irritation. We have found this method of feeding of value in infants with upper intestinal atresia.

After primary oesophageal anastomosis for atresia, oral feeds increase the risk of leakage. Although many cases have survived early feeding, we have in other cases used a polythene tube or a small catheter (number 4) passed *via* the nose and on through the anastomosis into the stomach for post-operative feeding. This procedure has not led to any obvious untoward effect, and the catheter has been left *in situ* for 7 - 12 days. On the other hand, the tube is too small for adequate gastric decompression immediately after operation, it interferes with the swallowing of saliva and healing of the anastomosis, and carries some risk of pharyngeal irritation. Consequently it may be better to perform a gastrostomy for post-operative feeding. This has the advantage that it can be kept open until there is no further risk of stricture at the site of anastomosis. We have used this method in a number of cases; it is popular in many American clinics.[19,62]

When the infant looks alert and sucks his fist, and normal bowel activity has returned and there is no mechanical hindrance to the passage of food, oral feeding is started. It is important that the initial feeds should be small, to minimize the risk of regurgitation and aspiration pneumonia. We have found the following a useful schedule:

5% glucose solution or Darrow's ..	1 dr.	1	hourly	for	3	feeds
	2 „	2	„	„	3	„
Expressed breast milk	3 „	2	„	„	3	„
	4 „	2	„	„	3	„
	5 „	2	„	„	3	„
	6 „	2	„	„	3	„
	1 oz.	3	„	„	3	„
	1½ „	3	„	„	8	„

It is dangerous, however, to write specific orders for oral feeding until it has been established that the infant's stomach can empty normally. The schedule must be modified from case to case and in the early stages it is wise to supplement it with intravenous fluids. When 1½ oz. feeds are successfully retained, the quantity is increased to meet the infant's requirements.

When feeds are given *via* a transanastomotic or gastrostomy tube it is convenient to allow them to drip in slowly from a dropper apparatus over a period of 15 - 20 minutes.

In cases with oesophageal atresia, gastrostomy or tube feeding is usually started after 36 hours and continued for 8 - 10 days. Swallowing of saliva commences after 36 hours, and ½ dr. of penicillin solution (10,000 units) is allowed by mouth every few hours thereafter. After 8 - 10 days 2 dr. of 5% glucose are tried by mouth. If there is no difficulty in swallowing and no leakage, expressed breast milk is given orally in increasing amounts while the feeds per tube are decreased *pari passu*. If a nasal tube has been used it is removed as soon as the infant can swallow adequately. If a gastrostomy has been made it is wise to leave the tube *in situ* for 6 - 8 weeks lest any subsequent difficulty in swallowing develops.

Premature babies and some full-term infants who are too weak to suck properly should be fed by gavage.[19] A small nasogastric tube is passed into the stomach, air is aspirated, the formula allowed to run in slowly, and the tube withdrawn.

CONCLUSION

In conclusion it would be as well to emphasize again the great importance of attention to detail and the value of organized team work in this type of surgery. The constant guiding principle in the post-operative care of children should be to anticipate complications and to treat them effectively in the incipient stage, before a full-fledged complication has become established.

Finally may I quote Willis Potts of Chicago, who said in 1958: 'In this still rather new field of paediatric surgery our object is singularly simple—better treatment of the surgical ills of childhood and more thoughtful attention to the correction of congenital malformations with which it is the misfortune of some children to be born.[45,46] The infant "with no language but a cry" asks that we make available to him the benefits of increased knowledge of his surgical diseases'.[47]

This paper is based on experience gained by team-work, and I am deeply grateful to all members of the 'team' who have helped to make this type of surgery possible in Cape Town. In particular I wish to thank our senior anaesthetist, Dr. Arthur Bull, without whom this work could never have developed, and also Dr. John Hansen for constant advice and guidance in his role as 'super-consultant' on problems in fluid therapy and all 'medical' matters.

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Last but not least, there are the resident medical staff and nursing staff. On them has depended the ultimate success of all the work, and they have stood up to the responsible task in a most admirable manner. Senior registrars never hesitated to 'special' the babies 'round the clock', and during busy periods often went without sleep for days on end. The ward sisters remained on duty long after their usual 'off-duty time' and provided first-class service despite almost insurmountable difficulties caused by shortage of nurses. It is difficult to thank them adequately, but they can at least share the reward which is greater than anything else in surgery, namely the satisfaction of having restored to health and many years of happiness these critically sick and deformed children.

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