Metabolic Results of Parenteral Feeding in Neonatal Surgery:

A Balanced Parenteral Feeding Program Based on a Synthetic 1-Amino Acid Solution and a Commercial Fat Emulsion

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THE ultimate success of operative surgery in the newborn is often dependent upon complete parenteral feeding for extended period of time. Preferably, the supply of nutrients should be sufficient to sustain normal growth. The nutritional requirements for normal growth and development in the neonatal period[7, 9, 13, 14, 15, 17, 18] cannot be met in a parenteral feeding program without certain difficulties at the present time. Due to limitations on the use of intravenous fat,[8, 10] the required 90–100 Cal./Kg./24 hr. in a fluid volume not exceeding about 140 ml./Kg./24 hr.[3] can be provided only through the use of strongly hypertonic carbohydrate solutions.[21] This hypertonicity rapidly causes phlebitis in peripheral veins; and, hence, necessitates the insertion of a catheter into a central vein. In addition, the hypertonic solution can lead to significant glucosuria with a resultant osmotic diuresis.

The introduction of an isotonic soy bean oil emulsion, *Intralipid* "Vitrum," which can be infused daily for several weeks without ill effects[8] has alleviated the hypertonicity problem. Since, however, not more than 2 Gm./Kg. body weight is recommended to be given per 24 hr., while mother's milk provides 4–6 Gm. fat/Kg. body weight[13, 20] per 24 hr., feeding with unphysiologically large amounts of carbohydrates is still necessary.

The present communication describes a parenteral feeding program which has been improved in several respects over those in current use.[1, 6, 21] The amount of soy bean oil emulsion has been increased to about 4 Gm./Kg. body weight/24 hr., which permits a decrease in the intake of carbohydrate to nearly physiological levels. This increased amount of fat can be administered by giving a small amount of heparin simultaneously to ensure the proper clearance of the fat from the serum. Furthermore, calcium and phosphate have been included in the program, to cover the needs of the growing skeleton and soft tissues.

The metabolic performance of the program has been evaluated on the basis of simultaneous balance data for nitrogen, potassium, magnesium, phosphorus, calcium, and sodium. The aim of this study was to test whether the proposed program contains the different constituents in amounts and proportions suitable to promote the synthesis of normal tissues at physiological rates. On the basis of our data, further improvements are suggested.

Materials and Methods

Clinical Material. Thirty-two newborns were placed on the parenteral feeding program described for periods ranging from

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TABLE 1. *Clinical Features of Patients Studied*

Patient	Sex	Birth Weight (Gm.)	Diagnosis	Operation	Age at Operation (Days)	Duration of Total Parenteral Feeding (Days)
K. O.	F	1,600	Aganglionosis of the small intestine	Ileostomy	3	7
E. F.	M	2,350	Ruptured omphalocele	Staged repair	1	26
R. K.	M	2,765	Omphalocele	Repair	1	8
O. J.	M	3,850	Diaphragmatic hernia	Repair	1	3

3–40 days postoperatively. Four infants from this group were selected for detailed metabolic studies. The clinical features of this latter group are shown in Table 1.

Parenteral Feeding. The parenteral feeding program was in each case adapted from the standard program which is in current routine use at the Rikshospitalet (Table 2). Table 3 compares this standard feeding program with the intake of several nutrients during normal breast feeding. The intake of mother's milk has been taken to be 130 ml./Kg. body weight per 24 hr.

TABLE 2. *Parenteral Feeding Program for Postoperative Newborns*

Preparation	Volume (ml./Kg./ 24 hr.)	Calories
Synthetic 1-amino acid solution (Aminofusin L-Forte "Pfrimmer")	30	24
Soybean oil emulsion (Intralipid 20% "Vitrum")	15–20	30–40
Invertose 10%	80–90	32–36
KH_2PO_4 (1 millimole/ml.)	1–2	
Calcium (0.5 mEq. Ca^{++}/ml.)	2	
Multivitamin solution (Pancebrin "Lilly")	0.2	
Total	125–140	86–100

The full program is attained through stepwise increases within the first week of life. Intralipid is administered through a separate infusion set. The other solutions as well as 500 I.U. heparin (3 mg.) per Kg. are mixed together and infused through another set. The two infusion sets are connected to a single needle or intravenous catheter through a Y-piece. Peripheral veins are used as the infusion route. The program is supplemented with plasma, 20% albumin concentrate, sodium bicarbonate or sodium chloride to correct for deficiencies or abnormal losses.

The solutions specified in Table 2, except Intralipid, were mixed together every morning, and infused over the next 24 hours at a constant rate. Simultaneously, the 20% Intralipid was infused through a separate infusion set, the two sets being connected at the orifice of the needle. Auxiliary solutions as plasma, 20% human albumin concentrate, and isotonic or hypertonic sodium bicarbonate were used as required. The fluids were administered through a needle in a scalp veins.

Collections and Balance Studies. Urine was collected in plastic bags permanently attached to the pubic skin. Only minor leakages occurred. The infant did not usually pass feces during the study period; the few small stools passed were not collected. Gastric aspirates were measured daily, but were pooled prior to analysis. Losses of aspirates did occur occasionally, but were of significance only in sodium balances.

Analytical Methods. Sodium and potassium in urine and gastric aspirates were measured by manual flame emission photometry in the routine laboratory. Calcium and magnesium were analyzed by atomic absorption spectrophotometry. Nitrogen was determined by the micro Kjeldahl method.

TABLE 3. *Comparison between Breast-Feeding and the Parenteral Feeding Program*

Contents of 130 ml.	Human Milk[1]	Absorption as Percentage of Intake[13]	Parenteral Feeding Program	Amounts/Kg./24 hr.
Calories	98		Calories	86–100
Nitrogen	0.43 Gm.[2]	84	Nitrogen	0.53 Gm.
Fat	5.4 Gm.	92[16]	Fat	3–4 Gm.
Lactose	9.6 Gm.		Carbohydrates	11–12 Gm.
K^+	2.3 mEq.	83	K^+	1.75–2.75 mEq.
$Mg.^{++}$	0.18 mEq.[3]	63	Mg^{++}	0.15 mEq.
Phosphate	21 mg. P	89	Phosphate	36–48 mg. P
Ca^{++}	1.7 mEq.	55	Ca^{++}	1 mEq.
Na^+	2.4 mEq.[4]	91	Na^+	1.05 mEq.

[1] Data reported by Slater.[13] Normal intake of milk is about 130/ml./Kg./24 hr.
[2] According to ref.[20] this figure is 0.3 Gm. N, of which 83% is protein N and 14% is Urea N.
[3] According to ref. [20] the amount of Mg^{++} is 0.43 mEq.
[4] Large variations in sodium content reported by Knutrud[11]: 0.5–2.9 mEq./130 ml.

Phosphorus was analyzed by the standard colorimetric technic.

Serum triglyceride levels in E. F. were determined in capillary blood samples. The samples were chilled in ice immediately to avoid further hydrolysis due to the lipoprotein lipase liberated by the heparin treatment. Laurell's method of analysis was used.[12]

Case Reports

In this section the clinical and metabolic course of each patient will be described briefly. The balance data will be analyzed in more detail in the discussion.

Case 1. K. O.: was a premature infant who at birth weighed 1,600 Gm. She suffered from aganglionosis of most of the small intestine. This condition led to vomiting and abdominal distension and was treated with an ileostomy. The disease was incompatible with life. The infant survived two operations, but died at 12 days of age from respiratory insufficiency. She was oliguric the last 3 days of life. Just prior to death, her weight was 1,800 Gm.

Balance data were recorded from the fifth day of life (Fig. 1, Table 4). Consistently positive balances of nitrogen, potassium, and magnesium were not obtained until the feeding program was improved on the fifth day of the balance study. This

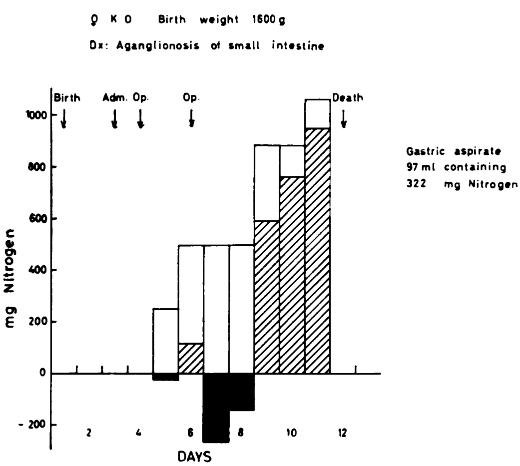


FIG. 1A. Nitrogen balance in K. O. Cross-hatched areas represent retention, clear areas represent excretion, and shaded areas represent negative balance. Note that the nitrogen balance was negative until the caloric and nitrogen content of the feeding program was increased. See text for further discussion.

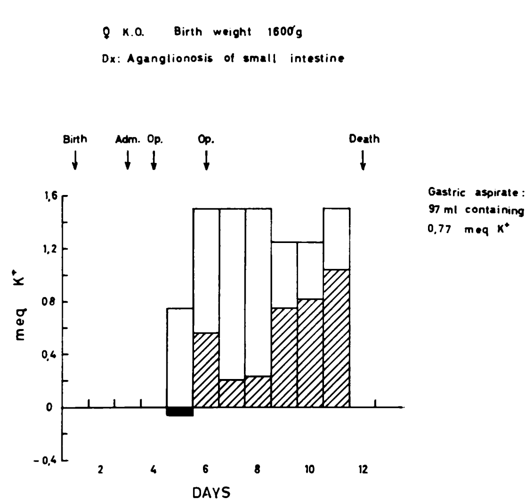


FIG. 1B. Potassium balance in K. O. (See legend for Figure 1A.)

TABLE 4. *Balance Data during Oral and Parenteral Feeding Analyzed and Compared in Terms of Nitrogen Balances and Element Retention Ratios*
Nitrogen Retentions and Element Ratios during Periods of Stable Growth (Consistently Positive Balances)

Element or Element Ratio	Muscle Tissue[4]	Breast-feeding[13]	Bottle-feeding[13]	Parenteral Feeding: Present Material K. O.	E. F.	R. K.	O. J.
Nitrogen mg.N/Kg./24 hr.		213 ± 48	304 ± 32	450[1]	238 and 335	183	407
K/N mEq./Gm.	2.8	5.6	6.7	1.7	4.1 and 5.5	7.8	4.0
Mg/N mEq./Gm.	0.71	0.61	1.8	0.29	0.37 and 0.29	0.48	0.32
P/N mg./Gm.	70	81	168		54[2] and 162	207[2]	56
Ca/P mEq./mmole		1.38	2.4		1.58[2] and 0.69	0.62[2]	0.57

[1] Period of inadequate nutritional supplies and about zero balances (first 4 days) excluded.
[2] Period preceding the introduction of phosphate and calcium in the feeding program (first 4 days) excluded.
The balance data on breast-feeding and bottle-feeding are taken from the work of Slater[13] who studied 22 babies in periods of 2–3 days from the 6th day of life. The composition of muscle tissue reported by Dickerson and Widdowson[5] is included to allow the retention ratios to be compared to the ratios which would be expected if growth of muscle or similar cells were mainly responsible for the positive balances.

patient was not given any phosphate (beyond the small amount in the lecithin of Intralipid) or any calcium. The use of heparin along with increased doses of Intralipid was not introduced until the next patient was studied.

Case 2. E. F.: was a premature male weighing 2,350 Gm. at birth who was born with a ruptured omphalocele. The defect in the abdominal wall was closed in four stages by means of silastic sheeting. Since the intestinal tract was partially obstructed and showed signs of impaired circulation, the infant was expected to need parenteral feeding for about 1 month. After 2 weeks of successful parenteral nutrition, parenteral feeding was terminated and oral feedings were attempted since there was no evidence of abdominal distention or vomiting. This decision proved unfortunate, however, since vomiting and aspiration occurred after 2 days. Parenteral feeding was resumed through a scalp vein. The feeding program was metabolically successful as demonstrated by the positive balances (Fig. 2, Table 4), but the infant died from sepsis and respiratory insufficiency. His weight 2 days before death was 2,400 Gm. Autopsy showed multiple abscesses in both kidneys and in the right adrenal gland. Fungal infection was noted in the brain and was probably responsible for convulsions observed occasionally during the course of his illness. At autopsy, there were no fat deposits in the liver, spleen, bone marrow, or reticuloendothelial system and there were no other abnormalities of

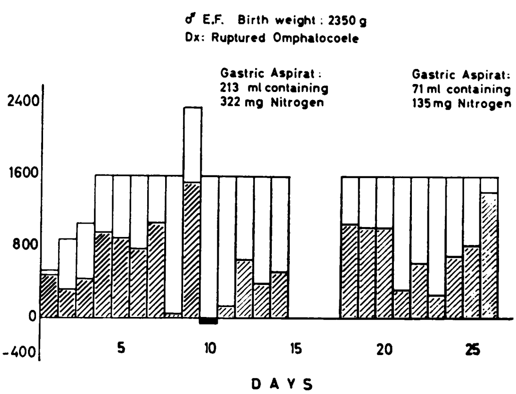


FIG. 2A. Nitrogen balance in E. F. Note the remarkable positive nitrogen balance in this very sick infant throughout the study period. The phosphate balance (Fig. 2C) was initially negative but then became positive once an adequate amount of phosphate was administered. Once calcium (Fig. 2E) was given to the infant, there was a very marked retention of it. See text for further discussion.

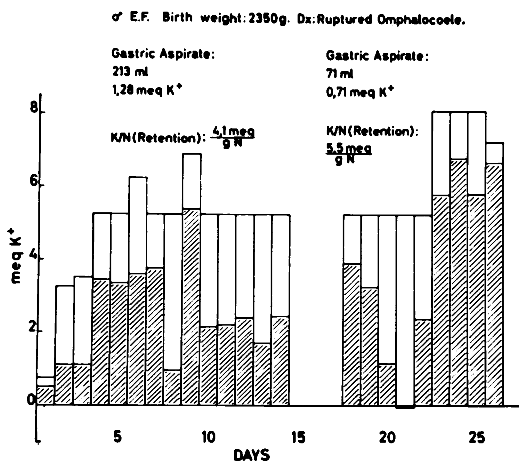


FIG. 2B. Potassium balance in E. F.

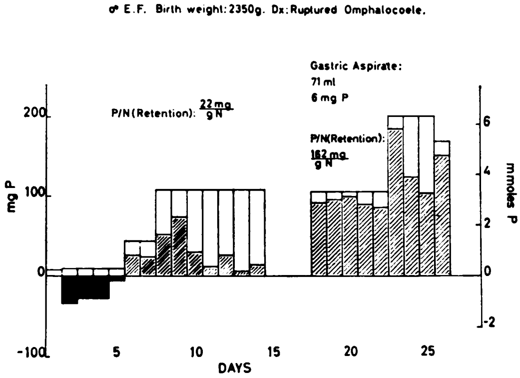


FIG. 2C. Phosphate balance in E. F.

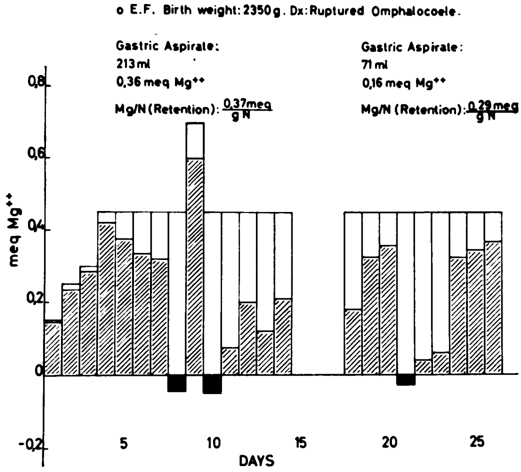


FIG. 2D. Magnesium balance in E. F.

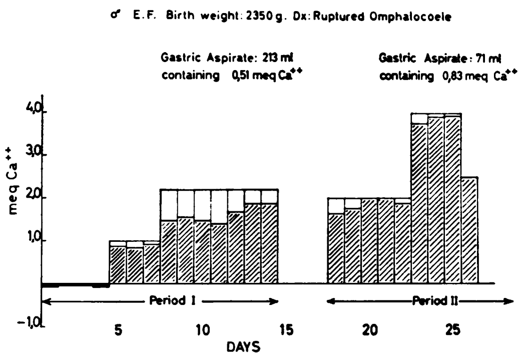


FIG. 2E. Calcium balance in E. F.

the liver. The parenteral feeding program was in accordance with the data in Table 2. Nitrogen, potassium, and magnesium were retained in amounts and ratios similar to normal infants on oral feeding as shown in Table 4.

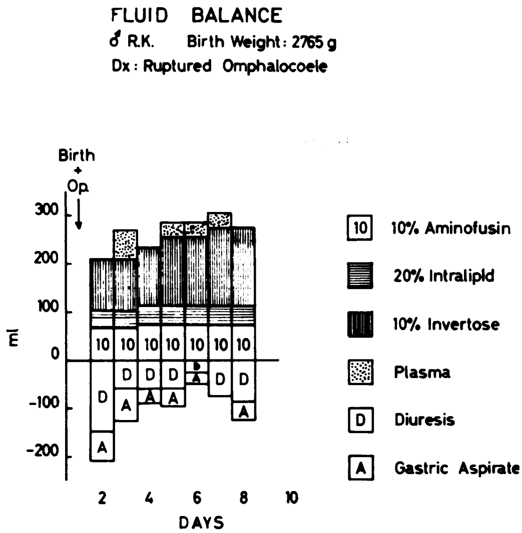
Case 3. R. K.: This infant boy was born at term, weighing 2,765 Gm., with a moderately large omphalocele, which was repaired surgically in one stage on the day of birth. The intestines seemed to be in good condition and unobstructed. The infant thrived on parenteral feeding administered through scalp veins for 8 days, and was transferred without difficulty to oral feeding. At the end of the parenteral feeding program, the weight was 3,000 Gm. His subsequent development has been normal.

The balance data of R. K. again show near normal retention of nitrogen, magnesium and potassium corresponding to buildup of new tissue (Fig. 3, Table 4). The phosphate and calcium balances demonstrate the effect of supplying these nutrients after a period of small or zero intake: 80–100% of the supply was retained, in the absence of any renal failure to cause abnormal, apparent positive balances. The fluid balance (Fig. 3) shows that between 30 and 65 ml. of plasma had to be given per day in the first week to replace the fluid aspirated from the stomach (317 ml. in all). The nitrogen content of the plasma has not been taken into account on the balance sheet.

Case 4. O. J.: was born at term, weighing 3,850 Gm., and was admitted to the pediatric surgical service on the day of birth in a moribund state due to impaired respiration. The underlying malformation, a diaphragmatic hernia, was corrected and the clinical state of the infant improved quickly. Parenteral feeding was stopped after 3 days and the child recovered uneventfully. The balance data correspond to a strongly anabolic phase, which was apparently adequately sustained by the parenteral feeding program employed. As in the case of R. K., surgical intervention was not followed by any postoperative catabolic phase

Results and Discussion

A parenteral feeding program for newborns should be easy to administer without complications and should sustain normal growth for extended period of time. Normal growth implies retention of all cellular constituents. Weight gain or nitrogen balance alone is not sufficient as a criterion of normal growth, but has to be supplemented with balance data for all other tissue constituents. Zero-balances may not be harmless to an infant since this could mean that some organs grow at the expense of others,



FIGS. 3A-F. Balance charts on R. K. As in E. F., the nitrogen balance (Fig. 3B) is positive throughout. The phosphate (Fig. 3D) and calcium (Fig. 3F) balances are initially negative and then become positive once adequate amounts are given. See the text for further discussion.

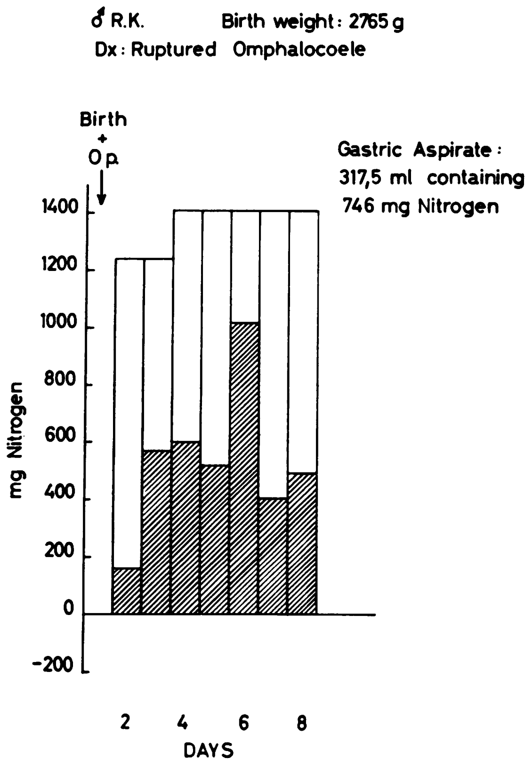


FIG. 3B. Nitrogen balance in R. K.

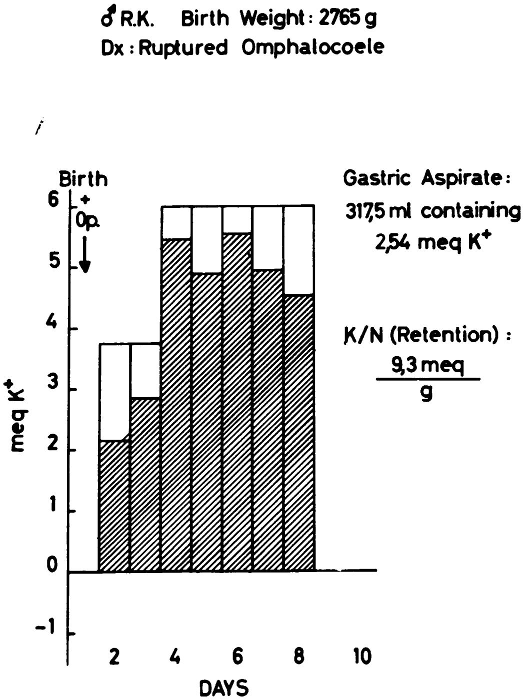


FIG. 3C. Potassium balance in R. K.

Infusion Technic

The present material and subsequent experience show that peripheral veins can be used in most cases for the administration of the feeding programs described in this pa-

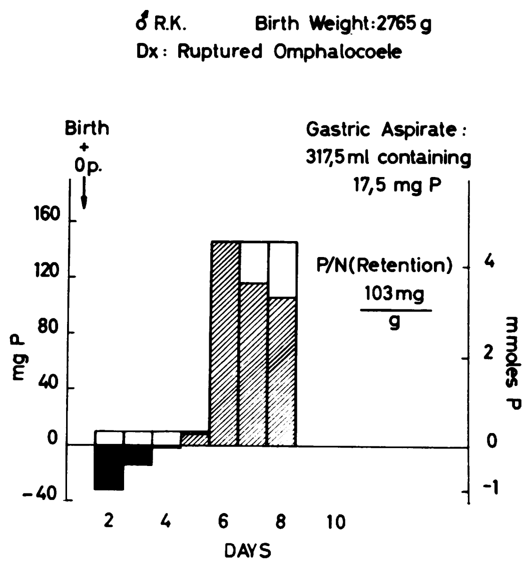


FIG. 3D. Phosphate balance in R. K.

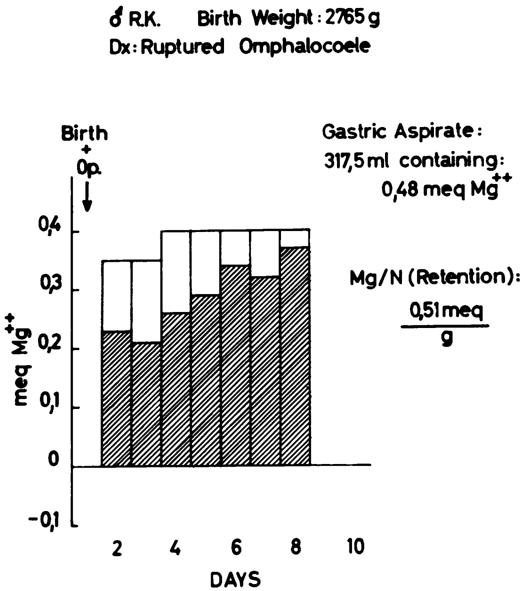


FIG. 3E. Magnesium balance in R. K.

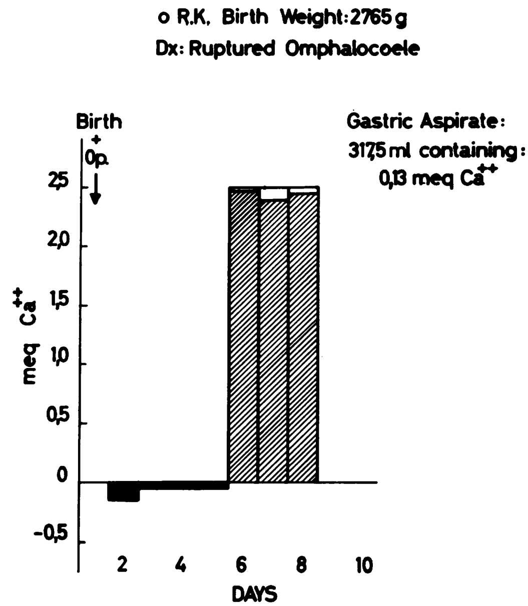


FIG. 3F. Calcium balance in R. K.

per for periods up to 4 weeks. A single peripheral vein usually tolerates infusions between 2 and 4 days. The amino acid solution and fat are administered simultaneously, both solution sets being joined at the entrance of the needle into the vein. We plan to investigate whether this period can be extended by adjustment of the pH of the infusion mixtures.

Nitrogen Balances and Protein Synthesis

Normal breast-fed newborns accumulate nitrogen at a rate between 150 and 250 mg. N/Kg. body weight in the first week of life.[13, 22] Bottle feeding increases nitrogen retention by about 100 mg.[13] Table 4 shows that our program supports positive nitrogen balances of the same magnitude as during bottle feeding, even during severe illness and in the immediate postoperative period. The nitrogen balance of K. O. did not, however, become positive until the infusion program was improved on the fifth day by the introduction of the 10% L-Aminofusin preparation. The amount of amino acids infused was thereby increased from about 2 to about 4 Gm./Kg. body weight per 24 hr., and the caloric value of the program was simultaneously increased from 56–72 Cal./Kg. body weight. Terminal oliguria with accumulation of urea may have contributed to the positive nitrogen balances of K. O. and E. F., but not to any extent which would alter the conclusion that the feeding program outlined in Table 3 does sustain protein synthesis at normal rates.

The nitrogen contents of plasma of 20% albumin concentrate have not been included in the balance charts as nitrogen intake, since only a small and unknown fraction of this was available for protein synthesis in the periods of study. The fractions of the infused plasma proteins which were catabolized within the periods of study, does, however, contribute to nitrogen excretion. Therefore, the true incorporation of nitrogen in newly synthesized protein was somewhat more extensive than the balance data indicate, especially in the case of R. K., who was given significant amounts of plasma, and in the case of E. F., who received 20% albumin concentrate.

We conclude that 3 Gm. of amino acids administered as L-Aminofusin 10% support a normal rate of protein synthesis when accompanied by an adequate caloric intake (90–100 Cal./Kg.). We have thus demonstrated that the high caloric intake used by Dudrick,[21] i.e., 128 Cal./Kg./24 hr., is not necessary to obtain large positive balances. It remains to be investigated whether a smaller total intake of nitrogen will be sufficient, especially if a more physiological amino acid mixture with a relatively lower amount of nonessential nitrogen (higher E/T ratio) is used. Such a decrease of the total load of nitrogen without reduction of the amount of essential amino acids infused, may be of importance in instances of impaired renal function or in the feeding of prematures who have a very high requirement of amino acids.[7] The efficient utilization of the infused nutrients which we have demonstrated, even in the immediate postoperative period, lends support to our current practice of attaining a full parenteral feeding schedule as early as the second or third day following the operation, even if this high intake would not be normal for a healthy infant at this early stage.

Potassium Balances and K/N Retention Ratios

The balance charts for potassium show that between 50% and 80% of the administered dose was retained. In the cases of E. F., R. K., and O. J., where the daily doses were between 2.0 and 2.5 mEq. $K+$/Kg., the ensuing K/N retention ratios were considerably in excess of the K/N ratio in muscle tissue (Table 4). This has also been found during normal oral feeding, as shown in Table 4.[13] The true K/N retention ratio of R. K. may, however, be somewhat lower than 7.8 mEq./Gm. since the nitrogen retention has been underestimated as discussed above.

In the case of K. O., the retention of potassium was relatively low, the K/N retention ratio being only 1.7 mEq. $K+$/Gm. nitrogen. The potassium supply of this patient was limited to about 1 mEq./Kg. daily due to her poor clinical state. Probably this dose of potassium was too low to permit adequate positive balance especially in the last three days of the study where the nitrogen retention was abnormally high (Table 4).

We conclude that the optimal daily dose of potassium appears to be about 2 mEq./Kg., provided, of course, that the concomitant supply of amino acids and calories is sufficient to permit normal nitrogen retention, and provided the clinical state of the patient is such that the body cells are able to absorb and retain the potassium they need.

Magnesium Balances and Mg/N Retention Ratios

Table 4 shows that the magnesium content of the parenteral feeding program outlined in Table 3 was insufficient to sustain a Mg/N retention ratio corresponding to breast feeding or to the composition of muscle tissue. The relative amounts of magnesium and amino acids in the parenteral feeding program would probably be more nearly correct if the supply of magnesium were increased from 0.15 to 0.3 mEq./Kg./24 hr. According to Table 3, this supply of magnesium would exceed the amount absorbed from mother's milk. This appears to be reasonable, however, because of the higher nitrogen retention during parenteral feeding (Table 4) than during breast feeding.

Phosphorus Balances and P/N Retention Ratios

In normal growth from infancy to adulthood, 80% of the retained phosphorus is deposited in the skeleton, the P/N element ratio of which is about 4,800 mg./Gm.,[4] while the remaining 20% is incorporated into soft tissues with a P/N element ratio close to 70 mg./Gm. (Table 4). The corresponding P/N retention ratio can be shown to be near 350 mg./Gm. The phosphorus content of human milk is too low, however, to sustain a P/N retention ratio of this magnitude (Table 4). Consequently, the mineralization of the skeleton must be very slow in the first months of life. This has been shown to be the case by Dickerson.[4] The supply of phosphorus rather than calcium in mother's milk has been shown to be rate limiting for the mineralization of bone tissue.[17, 18] Whether the intake of phosphorus during breast feeding is rate limiting for the synthesis of soft tissues is not known.

The balance studies performed in R. K. and O. J. show that phosphate intakes of about 1.6 mmoles/Kg./24 hr. may lead to P/N retention ratios between 60 and 200 mg./Gm. The duration of the studies was too short, however, to permit any stabilization of the P/N retention ratios. The balance data of E. F. are compatible with these figures. Although E. F. was studied for periods long enough to yield significant data, the interpretation of his balance data is complicated by episodes of renal failure, acidosis, and fever.

Since it is probably safe to establish a P/N retention ratio within the range defined by feeding with human milk and cow's milk mixtures, it appears reasonable to continue the balance studies with parenteral phosphate intakes near 1.5 mmoles/Kg., i.e. about twice the amount supplied by human milk.

Ca^{++}-Balances

During breast feeding, infants absorb about 1 mEq. of calcium per Kg. body weight daily, of which they retain about 70%.[13, 16–19] Feeding with cow's milk mixtures increases the absorption from the intestine to 4 mEq./Kg., of which as much as 97% is retained, probably due to the high phosphorus content of cow's milk.[13, 17]

In our patients between 90% and 100% of the administered calcium was retained. Table 4 shows, however, that the amount of calcium retained was smaller compared with the phosphorus retention than during oral feeding. The relatively low Ca/P retention ratios indicate that the supply of calcium should be increased from 1 mEq./Kg. to between 1.5 and 2 mEq./Ca^{++}/Kg./24 hr. The ratio of infused amounts of phosphate and calcium will then be similar to the ratio of the amounts absorbed from the intestine during breast feeding.

The strong retention of calcium confirms the view that it should definitely be included in parenteral feeding programs for newborns in order to sustain the normal growth of their skeletons. In infants, confinement to bed does not, of course, interfere with the mineralization of the skeleton, as it does in adults.

Na^+-Balances

Normal newborns retain about 2 mEq. Na^+ daily during the first week after breast feeding has been initiated.[11] Subsequently, a considerable sodium diuresis occurs. So far, it has not been possible to discern the shifts of extra- and intra-cellular sodium concentrations, fluid volumes, and uptake or release of sodium by the skeleton which underlie these balance phenomena.

K. O. experienced a sodium loss of about 0.5 mEq./24 hr., while the three other patients retained 2–5 mEq. Na^+/24 hr. These data are, however, subject to significant errors since the collection of gastric fluid, into which a major part of the sodium loss occurred, was not always complete. The sodium concentration of the fluid aspirated from the stomach varied between 10 and 15 mEq./l. Our current practice of replacing most of the fluid lost by this route with plasma thus overshoots the amount of sodium needed, and may be responsible for the slightly elevated sodium retention.

It does not make sense to specify a definite sodium requirement in the postoperative parenteral feeding of newborn infants, since most infants who need parenteral

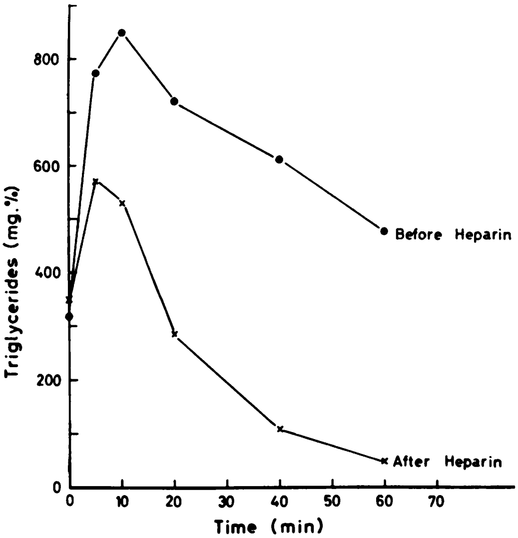


FIG. 4. Triglyceride disappearance curve in E. F. The resting level of triglyceride, before heparin, is markedly elevated, whereas, after heparin administration (1 mg. or 100 I.U., i.e., ½ mg./Kg.), the level is normal. In addition, heparin has also increased the rate of triglyceride clearance from the blood. See the text for further discussion.

feeding experience abnormal sodium losses. It appears, however, that the basic amount of sodium specified in Table 3 is suitable, provided sodium losses are adequately compensated for. About ⅓ to ½ of the fluid volume lost by vomiting or gastric suction should be replaced by plasma infusions. If large losses occur for long periods, it is desirable to analyze the amount of sodium lost and adjust the replacement therapy accordingly.

Intralipid and Heparin

A pilot study of the effect of heparin on the metabolism of intralipid was carried out in E. F. on the seventh day of life. Two hours after termination of the continuous infusion of Intralipid in the previous 24-hour period (3 Gm fat/Kg.), a sample of capillary blood was drawn for analysis of the triglyceride level of the serum. Then a volume of 20% Intralipid containing 0.4 Gm. fat/Kg. was injected intravenously over 20 seconds. The curve showing the subsequent clearance of the serum is seen in Figure 4. Three hours after the first injection, a similar experiment was carried out, this time preceded by an intravenous injection of 100 I.U. of heparin. Figure 4 demonstrates that the rate of disappearance of the fat from the blood increases considerably under the influence of this small amount of heparin. This indicates that the total lipolytic activity of the lipoprotein lipase of the body is increased by heparin. Furthermore, it appears from Figure 4 that the resting triglyceride level during a continuous infusion of Intralipid is elevated compared to the normal range of 50–150 mg./100 ml. Heparin appeared to markedly decrease this resting triglyceride level, although it remains to be investigated as to what the steady state triglyceride level is during the continuous infusions of Intralipid together with heparin.

A daily dose of 500 I.U. of heparin per infant has been selected for use in our present routine, until further experiments delineate the required minimal dose.[2] The mechanism of heparin-induced clearance of Intralipid is not necessarily such that the fatty acids are immediately available as metabolic fuel. The strongly positive balances reported in this paper would, however, scarcely be possible unless the Intralipid contributed its full share to the caloric supply. No adverse effects of the combined use of elevated fat doses and heparin have been observed in the present series or in the subsequent routine use of the method. The autopsy of E. F. did not reveal any evidence of abnormal accumulation of fat in the liver or other organs. It is unlikely that the simultaneous infusion of Intralipid and heparin is harmful, since this combination has been used extensively for several years to counteract venous thrombosis, although it has to be admitted that the dose of fat has been more moderate and the amount of heparin much larger than those employed in the present study.

Summary

A new program for the parenteral feeding of postoperative newborns has been evaluated. The regimen is based on a synthetic amino acid solution, Aminofusin L-Forte, "Pfrimmer" and a soy bean oil emulsion, Intralipid 20%, "Vitrum."

This program has two major advantages over ones utilizing hypertonic glucose as the major source of calories. First, glucose intolerance with glucosuria and osmotic diuresis is no longer a problem. Furthermore, the reduced hypertonicity due to the liberal use of the isotonic fat emulsion allows the feeding program to be administered entirely through peripheral veins for periods up to about 3 weeks.

The feeding program has been shown to sustain retention of nitrogen and minerals in amounts and ratios similar to those found in normal newborns, even in the immediate postoperative period. Detailed analysis of balance data shows that the content of calcium and magnesium in the program should be increased somewhat, while the amount of nonessential nitrogen should be reduced.

Thirty-two newborns have been on the program so far, and of these 26 have survived. Furthermore, 14 infants with serious complications following operation have been maintained on the same parenteral regimen with 100% recovery. These results in selected high-risk groups appear promising in view of the over all survival rate of 80% in neonatal emergencies in this department.

References

1. Borresen, H. C. and Knutrud, O.: Parenteral Feeding of Neonates Undergoing Major Surgery. Acta Paediat. Scand., **58**:420, 1969.
2. Coran, A. G. and Nesbakken, R.: The Metabolism of Intravenously Administerad Fat in Adult and Puppy Dogs. Surgery (in press).
3. Darrow, D.: The Physiologic Basis for Estimating Requirements for Parenteral Fluids. Pediat. Clin. N. Amer., **11**:819, 1964.
4. Dickerson, J. W. T.: Changes in the Composition of the Human Femur During Growth. Biochem. J., **82**:56, 1962.
5. Dickerson, J W. T. and Widdowson, E. M.: Chemical Changes in Skeletal Muscle During Development. Biochem. J., **74**:247, 1960.
6. Filler, R. M., Eraklis, A. J., Rubin, V. G. and Das, J. B.: Long-term Total Parenteral Nutrition in Infants. New Eng. J. Med., **281**: 589, 1969.
7. Gordon, H. H.: Protein Allowances for Premature Infants. JAMA, **175**:107, 1961.
8. Hallberg, D., Schuberth, O. and Wretlind, A.: Experimental and Clinical Studies with Fat Emulsion for Intravenous Nutrition. Nutr. Dieta., **8**:245, 1966.
9. Holt, L. E., Jr. and Snyderman, S. E.: The Amino Acid Requirements of Infants. JAMA, **175**:100, 1961.
10. Jean, R.: Tolerance clinique, anatomique et biologique de l'organisme aux perfusions d'emulsions de lipides chez l'enfant. Ann. Anesth. Franc. VII, **4**:65, 1966.
11. Knutrud, O.: The Water and Electrolyte Metabolism in the Newborn Child After Major Surgery. Universitetsforlaget, Oslo, Norway, p. 53, 1965.
12. Laurell, S.: A Method for Routine Determination of Plasma Triglycerides. Scandinav. J. Clin. and Lab. Investigation, **18**:668, 1966.
13. Slater, J. E.: Retentions of Nitrogen and Minerals by Babies One Week Old. Brit. J. Nutr., **15**:83, 1961.
14. Snyderman, S. E., Holt, L. E., Jr., Dancis, J., Raitman, E., Boyer, A. and Balis, M. E.: Unessential Nitrogen: A Limiting Factor for Human Growth. J. Nutr., **78**:57, 1962.
15. Snyderman, S. E., Boyer, A., Raitman, E., Holt, L. E, Jr. and Prose, P. H.: The Histidine Requirement of the Infant. Pediatrics, **31**:786, 1963.
16. Southgate, D. A. T., Widdowson, E. M., Smits, B. J., Cooke, W. T., Walker, C. H. M. and Mathers, N. P.: Absorption and Excretion of Calcium and Fat by Young Infants. Lancet, **1**:487, 1969.
17. Widdowson, E. M., McCance, R. A., Harrison, G. E. and Sutton, A.: Effect of Giving Phosphate Supplements to Breast-fed Babies on Absorption and Excretion of Calcium, Strontium, Magnesium, and Phosphorus. Lancet, **2**:1250, 1963.
18. Widdowson, E. M. and McCance, R. A.: The Metabolism of Calcium, Phosphorus, Magnesium, and Strontium. Pediat. Clin. N. Amer., **12**:595, 1965.
19. Widdowson, E. M., Slater, J. E., Harrison, G. E. and Sutton, A.: Absorption, Excretion, and Retention of Strontium by Breast-fed and Bottle-fed Babies. Lancet, **2**:941, 1960.
20. Williams, H. H.: Differences Between Cow's and Human Milk. JAMA, **175**:104, 1961.
21. Wilmore, D. W., Groff, D. B., Bishop, H. C. and Dudrick, S. J.: Total Parenteral Nutrition in Infants with Catastrophic Gastrointestinal Anomalies. J. Pediat. Surg., **4**:181, 1969.
22. Woodruff, C. W.: Protein Requirements of Full-term Infants. JAMA, **175**:107, 1961.