Intravenous Feeding in Infants

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The maintenance of nutrition by the intravenous route for long periods has been made possible by the recent availability of more suitable nutrient solutions, and, in carefully selected instances, represents an important advance in the management of certain diseases in infancy (Wilmore and Dudrick, 1968; Borresen, Coran, and Knutrud, 1970; Filler and Eraklis, 1970; Schwachman, Filler, and Khaw, 1970; Hyman *et al.*, 1971). There remain, however, many serious problems which limit the more widespread use of this form of treatment in infants, and some of these have been reported by Groff (1969), Kaplan *et al.* (1969), Ashcraft and Leape (1970), Michener and Law (1970), and Harries (1971). The technical problems involved, the optimal nutritional requirements, and the fundamental differences in the nutritional demands of the growing infant present special problems when compared with those of the older child or adult.

This paper presents a practical guide to intravenous feeding in infancy (i.e. children under the age of 6 months) and is concerned in the main with 'complete' intravenous feeding, that is to say, the provision of nutrition exclusively by the intravenous route. Most of the information, however, is also applicable to the use of intravenous feeding as a supplement to oral feeding when the latter is inadequate for some reason. It has been formulated as a result of experience at The Hospital for Sick Children, from discussions with colleagues at other centres, and from a review of the literature.

A: Indications and Contraindications

Indications. The decision as to when to institute intravenous feeding is difficult and essentially based on clinical grounds; the need for improved nutrition to maintain life or reduce morbidity has to be carefully weighed against the serious complications which can occur. This form

of treatment should only be considered when nutrition cannot be maintained by the oral route, and when there is good reason to expect that such a state will be prolonged and pose a serious threat to the health or life of the child. Beneficial results have been reported (Dudrick *et al.*, 1969; Rickham, 1967; Wilmore and Dudrick, 1968; Borresen *et al.*, 1970; Filler and Eraklis, 1970; Michener and Law, 1970; Schwachman *et al.*, 1970; Hyman *et al.*, 1971) in the following conditions: (i) neonatal surgery involving extensive resection or reimplantation; (ii) protracted diarrhoea unresponsive to dietary treatment; (iii) extreme prematurity; and (iv) renal failure.

In older children intravenous feeding may also be indicated in conditions such as coma and disorders of swallowing as might occur in poliomyelitis, tetanus, or following severe trauma. Children with extensive burns may also benefit from intravenous feeding.

Contraindications. The maintenance of complete intravenous feeding requires the strictest of aseptic techniques, intensive nursing care, and frequent biochemical monitoring using micro-techniques which allow blood tests to be performed on small aliquots obtained from capillary blood. If such facilities are not available, it seems wiser to transfer the infant to an appropriate centre.

Acidosis and/or dehydration must be corrected before instituting intravenous feeding, particularly when hypertonic or fructose-containing solutions are to be used (Harries, 1971).

The use of fat emulsions is contraindicated in patients with hyperlipidaemia from any cause, when there is evidence of impaired bone-marrow function or when liver function is severely impaired. In children with mild liver dysfunction, fat emulsions should be used cautiously, and daily estimations of serum transaminases are necessary; in addition, daily inspection of serum for turbidity is essential in order to ensure that the infused fat is being cleared from the circulation.

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B: Nutrient Constituents Required for Complete Intravenous Feeding

The constituents of any 'complete' intravenous feeding programme should include calorie sources, water, nitrogen, vitamins, and the biologically important minerals, including the 'trace metals', in amounts and proportions that will result in their efficient utilization for the purposes of tissue repair and growth. A number of nutrient solutions are currently available.

Amino acid solutions. The composition of 5 amino acid solutions currently available in the U.K. is shown in Table I. Amino acid infusates are prepared either by hydrolysis of natural protein when the amino acids are present in the L-form (aminosol prepared from casein) or by synthesis of the individual amino acids when they may be present as a mixture of the D- and L-forms (Trophysan) or entirely as the L-forms (Vamin and Aminosol-fuscin). L-amino acids are known to be more effective than D-amino acids in maintaining positive nitrogen balance and promoting protein synthesis (Jarnum *et al.*, 1969; Peaston, 1968). Most amino acid solutions contain a non-nitrogenous source of calories such as glucose, fructose, ethanol, or sorbitol, and the manufacturers normally include the caloric value of the amino acids in the total caloric content of the solution.

During periods of rapid growth and tissue repair, demands for certain 'non-essential' amino acids may exceed endogenous synthesis so that they become 'essential' or 'semi-essential'. In addition to the 8 amino acids known to be essential to adults (Rose, 1949), histidine is also essential to the growing infant (Holt, 1967). Recent evidence suggests that proline (Harries *et al.*, 1971), alanine (Jurgens

and Dolif, 1968), and cystine or cysteine (Sturman[†] Gaull, and Raiha, 1970) may also be 'essential' or 'semi-essential' to the infant. Aminosol-fructose-ethanol (AFE) and Vamin contain all the amino acids necessary for the growing infant, and in addition their proportionate amounts are similar to those in human milk protein (McCance and Widdowson, 1960). Trophysan contains neither histidine nor proline, nor does it have cystine, and compared with human milk protein there is a considerable difference in the proportionate amounts of certain other amino acids (McCance and Widdowson, 1960); in addition these amino acids are present in the unsatisfactory D-form. There are, therefore, good theoretical reasons for considering Trophysan unsuitable for use in infancy. The caloric value of Vamin and AFE is far greater than that of any of the other preparations (Table I), and thus they are most appropriate to the demands of the growing infant; their osmolality, however, is extremely high owing to their high solute concentrations, and this is particularly the case for AFE (osmolality, 1975 mOsm/l.). With the exception of Trophysan the high concentrations of sodium must be borne in mind when calculating requirements, and the very high concentration present in Aminosol 10% (160 mEq/l.) precludes its use in infants. The concentration of potassium, an important electrolyte, particularly with regard to protein synthesis, in Vamin and Trophysan is 20 and 8 mEq/l., respectively, whereas in the other amino acid solutions the amounts are negligible (0.15 mEq/l.).

Aminosol-fructose-ethanol and Vamin are probably the amino acid solutions of choice in infancy. They contain 15% and 10% fructose, respectively; because infusions of fructose at rates greater than

TABLE I
Composition of Amino Acid Solutions Available in U.K.
(all values per litre)

Solution	Calories*	Non-nitrogenous Sources of Calories (g)	Amino Acids (g)	Sodium (mEq)	Potassium (mEq)	Chloride (mEq)	Calcium (mEq)	Magnesium (mEq)	Osmolality (mOsm)	pH
Aminosol-Fructose-Ethanol†	875	Fructose 150 Ethanol 25	33	53	0.15	43	—	—	1975	5
Aminosol 10%†	330	—	100	160	0.5	130	—	—	925	5
Aminosol Glucose‡	300	Glucose 50	33	53	0.15	43	—	—	555	5
Trophysan 5‡	364	Sorbitol 49	40	6-10	8	<2	—	—	6.3-6.5	5.2
Vamin†	650	Fructose 100	70	50	20	55	5	3	1275	5.2

*Includes caloric value of amino acids.

†Manufactured by Vitrum, Sweden. Distributed by Paines and Byrne Ltd., England.

‡Manufactured by Egic, France. Distributed by Servier Laboratories Ltd., England.

0.3 g/kg per hr may result in severe metabolic acidosis (Andersson, Brohult, and Sterner, 1969; Harries, 1971), AFE and Vamin should not be given at rates exceeding 48 ml and 72 ml/kg per 24 hr, respectively. Dehydration and/or acidosis must be corrected before administering either of these solutions. Vamin has recently become available in the U.K. and because of its theoretical advantages over AFE, will probably become accepted as the most suitable solution.

Fat emulsions. The composition of 4 widely used fat emulsions is shown in Table II. Our experience is limited to Intralipid (10% or 20%) which is prepared from fractionated soybean oil. The emulsion is stabilized with egg phosphatide and the water phase made isotonic by the addition of 2.5% glycerol. The fat is present mainly in the form of triglycerides. A greater proportion (85%) of the total fatty acids are unsaturated in comparison with human milk (approximately 50%), mainly due to the higher proportion of linoleic acid (54.4%) contained in Intralipid. In addition to linoleic acid, Intralipid contains oleic (21.7%), linoleic (7.2%), and the saturated fatty acids palmitic (11.4%) and stearic (3.4%) acids.

No serious side-effects have been reported. In a large series of adults, Schuberth and Wretling (1963) infused doses of 1–2 g fat/kg per day and observed side-effects in less than 3% of patients (two-thirds had fevers or chills and the other third had a variety of minor symptoms). Hadfield (1966) gave much larger doses (6–9 g fat/kg per day) without any untoward effects, and in one patient with fulminating ulcerative colitis, no side-effects were reported with doses as high as 12 g fat/kg per day. Hallberg *et al.* (1967) noted transient prolongations of bromsulphalein retention and an increase of transaminase values in adults receiving 1.5–2.6 g fat/kg per day. Liver biop-

sies following prolonged infusions of Intralipid have shown pigmentation of the Kupffer cells (Lawson, 1965; Thompson *et al.*, 1965), but the significance of these findings is not clear. In neonates and older infants, Intralipid has been used in doses of 2–4 g fat/kg per day without side-effects (Rickham, 1967; Borresen *et al.*, 1970; G. Grotte, personal communication), and our experience using similar doses is in agreement. The fat particles in 10% Intralipid are less than 1 μ in diameter but are somewhat larger in the 20% preparation; and are rapidly cleared from blood and metabolized (Reid, 1967). Gustafson *et al.* (1970) investigated clearance rates after rapid infusions of 20% Intralipid in doses of 0.1 or 0.5 g fat/kg body weight in low birthweight infants during the first 6 hours of life. From the total serum lipid disappearance curves they calculated the maximum removal capacity of infused fat from the intravascular compartment to correspond to 6 to 8 g fat/kg per 24 hr in 'preterm' babies, whereas in 'small-for-dates' babies disappearance rates were considerably less. Borresen *et al.* (1970) studied the effect of heparin (50 IU/kg) on the rate of disappearance of serum triglyceride in a 7-day-old infant after the administration of 20% Intralipid (0.4 g fat/kg given over 20 sec), and observed a considerable increase in clearance rate compared to when the fat was given alone. They did not, however, investigate steady-state triglyceride levels during continuous infusion of Intralipid and heparin. There is virtually no information available on the clearance and metabolism of intravenously administered fat in sick infants, and in the light of current knowledge it seems advisable to restrict the total daily dose of Intralipid to a maximum of 4 g fat/kg per day, the rate of infusion not exceeding 0.5 g fat/kg per hour. It should be introduced in a dose of 1 g fat/kg per day and, if daily inspection of serum (4–5 hr after completion of fat infusion) indicates that the fat

TABLE II
Composition of Fat Emulsions
(all values in g per litre)

Preparation	Soybean Oil	Cottonseed Oil	Phospholipids*	Glycerol	Sorbitol	Xylitol	α -Tocopherol
Intralipid 20%†	200		12	25			0.2
Lipofundin S 20%‡	200		15			50	
Lipophysan§		150	20		50		0.5
Lipofundin‡		100	7.5		50		0.585

*In Intralipid the phospholipids contain mostly phosphatidyl choline and in addition approximately 25% phosphatidyl ethanolamine. The phospholipids contained in Intralipid and Lipophysan are derived from egg yolk, and those in Lipofundin S 20% and Lipofundin from soybean.

†Manufactured by Vitrum, Sweden. Distributed by Paines and Byrne Ltd., England.

‡Braun, Germany.

§Manufactured by Egic, France. Distributed by Servier Laboratories Ltd., England.

is being cleared, increased by increments of 1 g fat/kg per day. Borresen *et al.* (1970) include a daily dose of 500 IU heparin in their regimen, but as yet there is no positive evidence that the addition of heparin enhances the metabolism of fat in sick infants receiving prolonged infusions. Fat infusions may interfere with certain blood tests, and the laboratory should therefore be informed when samples are sent from such patients.

Monosaccharides. There is still disagreement regarding the monosaccharide of choice for use as a calorie source in intravenous feeding, and the relative merits of glucose, fructose, or mixtures of glucose and fructose (invert sugar) have been extensively reviewed (Geyer, 1960).

It is often stated that fructose is less irritant to veins than glucose, but there is no good published evidence to support this concept. Since it is less dependent on insulin for its further metabolism (Chernick and Chaikoff, 1951; Miller *et al.*, 1952), fructose might be preferred when insulin activity is impaired such as in diabetes or renal failure.

Tissue uptake of fructose is more rapid than glucose and urinary sugar losses, and osmotic diuresis might therefore be anticipated to be less with the former sugar (Weichselbaum, Elman, and Lund, 1950; Miller *et al.*, 1952; Ashare, Moore, and Ellison, 1955). The renal threshold for fructose is, however, considerably less than that for glucose (Woodyatt, Sansum, and Wilder, 1915; Cori and Cori, 1927), and Lane and Dodd (1957) found urinary losses of fructose to be greater than for glucose when these sugars were infused at rapid rates (1.25 g/kg per hr) to children. Thus, at high rates of infusion, fructose may result in a greater osmotic diuresis than glucose. Both monosaccharides may result in increased urinary losses of phosphate, sodium, and potassium (Miller *et al.*, 1952; Ashare *et al.*, 1955). The severe metabolic acidosis that may occur with fructose infusion has already been mentioned. Hypoglycaemia has also been reported during infusions of fructose (Sahebajami and Scalettar, 1971).

Glucose still has much to commend it, and at present it is probably advisable that at least 50% of the infused carbohydrate should be given as glucose to infants receiving intravenous feeding.

Other calorie sources available for intravenous feeding

Ethyl alcohol. Alcohol provides 7 calories/g and is included in aminosol-fructose-ethanol in a concentration of 2.5 g/100 ml (Table I). Its toxicity limits its use in infants, and it may cause

increased losses of urine owing to its inhibitory action on antidiuretic hormone release.

Sorbitol. Sorbitol* is a polyhydric alcohol of glucose which is initially metabolized to fructose and subsequently incorporated into liver glycogen (Wick, Almen, and Joseph, 1951). In the experimental animal it follows a similar metabolic pathway to fructose (Stetten and Stetten, 1951) and is thus less dependent on insulin for its further metabolism. In adults it has been used extensively as a source of calories in intravenous feeding (Murasco *et al.*, 1966) but has not yet been fully evaluated in children.

Vitamins. The exact requirements of intravenously administered vitamins, particularly in sick infants, are not known, and the values given in Table III are based on the information available on oral requirements. An intravenous preparation containing all the essential vitamins in the recommended proportions is not yet available, but the manufacture of such a preparation is at present under investigation.†

TABLE III
Daily Vitamin Requirements in Infancy

Vitamins	Recommended Oral Requirements	Given Intravenously
A	1500 IU*	3000 IU‡
B ₆	0.2–0.3 mg*	4.5 mg‡
B ₁₂	1 µg†	1 µg
C	30 mg*	150 mg‡
D	400 IU*	300 IU‡
E	—	1.5 mg‡
K	1.5 mg†	1.0 mg
Thiamine	0.4 mg*	15 mg‡
Riboflavine	0.6 mg*	3 mg‡
Niacin	6.0 mg*	30 mg‡
Dexpantenol	—	7.5 mg‡
Folic acid	0.35 mg†	0.5 mg

*Nelson, Vaughan, and McKay (1969).

†Wilmore and Dudrick (1968).

‡Contained in 3.0 ml 'multivitamin infusion'.

At present, 'multivitamin infusion'‡ should be given in a dose of 3.0 ml/day together with folic acid (0.5 mg/day). Vitamin K (3 mg twice weekly) and vitamin B₁₂ (100 µg once monthly) are also necessary. If intravenous feeding is continued for longer than 1 week, biotin (0.5 mg/day) and choline chloride (150 mg/day) should also be included.

*Manufactured by Egic, France. Distributed by Servier Laboratories Ltd., England.

†Paine and Byrne Ltd.

‡Manufactured by Multivitamin Infusion. U.S. Vitamin and Pharmacy Co. Distributed by T. J. Sass, London.

Minerals. The quantities of sodium, potassium, calcium, and magnesium are based on the data of Nelson, Vaughan, and McKay (1969), Wilmore *et al.* (1969), and Borresen *et al.* (1970), and have been found to be adequate in practice. Iron ('Imferon')* 0.5 ml by deep intramuscular injection every 2 weeks provides requirements (1 mg/kg per day). 'Trace metals' are administered as weekly infusions of plasma (10 ml/kg).

C: Techniques and Organization of Intravenous Feeding Regimen

Choice of vein. The risk of septicaemia is increased when using intravenous catheters (Darrell and Garrod, 1969; Groff, 1969; Kaplan *et al.*, 1969; Wilmore *et al.*, 1969; Aschraft and Leape, 1970; Banks *et al.*, 1970), particularly when central venous catheters are used in sick infants whose resistance to infection may be impaired (Groff, 1969; Filler and Eraklis, 1970). We have observed septicaemia in 4 infants who received intravenous feeding via superior vena caval catheters, and in 2 the same organism was cultured from blood and catheter tip (Table IV). Case 4 developed staphylococcal septicaemia with multiple lung abscesses which may have resulted from septic emboli arising from the catheter tip which was placed in the right atrium; necropsy was not performed.

TABLE IV

Organisms Cultured from Blood and Catheters in Four Infants with Superior Vena Cava Catheters

Infant	Blood Culture	Catheter Culture
1	Coagulase-positive staphylococcus	Proteus and klebsiella
2	<i>Strep. faecalis</i>	<i>Strep. faecalis</i> and <i>Candida albicans</i>
3	<i>Candida albicans</i> and achromobacter	Sterile
4	Coagulase-positive staphylococcus	Coagulase-positive staphylococcus

In addition to the risk of septicaemia, central vein catheters may cause venous obstruction. We have seen this complication in 3 infants; in 2 the superior vena cava became obstructed on the 10th and 15th days of intravenous feeding, and in 1 of these patients necropsy showed an antemortem thrombus 1 cm long just below the catheter tip. In the other infant inferior vena caval obstruction followed the infusion of 270 ml AFE over a 26-hour period and was confirmed by a venogram; the signs of obstruction disappeared after removal

of the catheter. Groff (1969) described an infant who developed superior vena caval obstruction after 35 days of treatment and, as in our patient, signs of obstruction rapidly disappeared when the catheter was removed.

All peripheral veins should, therefore, be utilized (using scalp vein needles as far as possible) before resorting to central veins such as the superior or inferior vena cava. The maintenance of intravenous feeding via peripheral veins is difficult owing to the frequent occurrence of phlebitis and venous obstruction caused by the hypertonic infusates. The inclusion of Intralipid (which is isotonic and non-irritant to veins) in the regimen reduces the need for such large volumes of hypertonic carbohydrate infusions as sources of calories, and thus may reduce the frequency of peripheral venous obstruction. Using Intralipid in doses of 4 g fat/kg per day, we have found it possible to maintain complete intravenous feeding in infants for periods of up to 3 weeks via peripheral veins, and similar results have been reported by Borresen *et al.* (1970). Frequent (at least once every 24 hours) changes in drip sites are usually necessary to ensure adequate flow of the infused solutions. Catheterization of peripheral veins should be performed under full aseptic precautions preferably in the operating theatre. The role of heparin (500 IU/day) in preventing venous obstruction is not at present clear.

The technique of superior vena caval catheterization has been described in detail by Wilmore and Dudrick (1968), and should be reserved for those infants in whom all peripheral veins have been utilized, and in whom the need for intravenous nutrition is critical.

Intravenous feeding regimen. The regimen used for 'complete' intravenous feeding is shown in Table V, and its nutrient composition is compared with that provided by the volume of human breast milk which a normal infant might consume (Table VI). Due to variable absorption, the amount of each component of breast milk actually absorbed will be somewhat less than that shown in Table VI.

Though formal nitrogen-balance studies have not been performed, the weight gain of infants receiving this regimen suggests that the infused amino acids are being utilized for purposes of protein synthesis and growth. Borresen *et al.* (1970) found newborn infants to be in positive nitrogen balance when given 86–100 calories and 0.53 g nitrogen/24 hr intravenously for short periods of time. The same workers also performed balance studies on potassium, magnesium, and calcium, and their

*Benger Laboratories, England.

TABLE V
Regimen for 'Complete' Intravenous Feeding of Infants
(all values per kg/24 hr)

Solution	Volume (ml)	Calories	Amino Acids (g)	Sodium (mEq)	Potassium (mEq)	Chloride (mEq)	Calcium (mEq)	Magnesium (mEq)
Vamin	50	34	3.5†	2.5	1.0	2.5	0.25	0.15
15% Glucose	70	42						
20% Intralipid	20	36						
MgSO ₄ (1 mEq Mg ⁺⁺ /ml)	0.3							0.3
K ₂ HPO ₄ (1 mEqK ⁺ /ml)	1.0				1.0			
10% Calcium Gluconate (0.5 mEq Ca ⁺⁺ /ml)	3.5						1.75	
Total	145.3*	102	3.5	2.5	2.0	2.5	2.0	0.45

*Due to osmotic diuresis total fluid volume may need to be increased using 4.5% dextrose in 0.18% saline.

†Caloric value included in total calories.

TABLE VI
Comparison Between Contents of Breast Milk and Intravenous Feeding Regimen (Table V)

	Quantities Received per kg/Body Weight per 24 Hours									
	Calories	Nitrogen† (g)	Fat (g)	Carbohydrates (g)	Sodium (mEq)	Potassium (mEq)	Magnesium (mEq)	Calcium (mEq)	Chloride (mEq)	Phosphorus (mEq)
Breast milk (165 ml)*	120.4	0.31	8.4	11.0	0.82	2.2	0.4	2.3	2.9	2.0-3.6
IV feeding regimen	102	0.47	4.0	15.5	2.5	2.0	0.45	2.0	2.5	2.5

*Contents human breast milk calculated from McCance and Widdowson (1960), assuming normal infant consumes 165 ml/kg/24 hr.
†Caloric value of proteins and amino acids included in total calories. Calories (from non-nitrogenous sources) per 1.0 g nitrogen in milk and IV feeding regimen = 388 and 210 respectively.

results suggest that the amounts shown in Table V are adequate.

In practice the volumes of each nutrient solution are increased in a stepwise fashion, maximum volumes being achieved after 4 to 5 days of starting intravenous feeding (see Fig.). On the first day, approximately a third of the total fluid requirements (150 ml/kg per 24 hr) are administered as 20% Intralipid, 15% glucose, and Vamin, the remaining fluid being provided as 4.3% glucose in 0.18% saline. If the infant's clinical and biochemical condition is satisfactory, the volumes of each of the infusates are doubled on the second day, and after a further 2 to 3 days the volumes are increased to correspond with those shown in Table V. Each nutrient solution is delivered in small volumes, and they are alternated with each other so that the total volume of any one solution administered is evenly distributed throughout the 24-hour period. This can be arranged by constructing a series of two-way taps to which 4 or 5 separate drip set units can be attached; alternatively, two different solutions can be concurrently infused through a Y-shaped connecting tube.

The regimen which has been described applies to 'complete' intravenous feeding. A regimen shown for days 1 or 2 (see Fig.), however, can be used to supplement oral feeding when the latter is considered to be inadequate. In these circumstances careful calculation of both oral and intravenous nutrients is important in order to avoid excesses or deficiencies of any single nutrient substance.

No solution should be added to Intralipid, and because of the risk of bacterial contamination, drugs, vitamins, or electrolytes must not be added to amino acid or carbohydrate infusates. In addition, several drugs (e.g. penicillin, fucidin, papaverine, and adrenaline) are known to be unstable in certain infusates due to their low pH and the interactions that may occur between the constituents of the infusate and the drug (*British Medical Journal*, 1970). Vitamins and electrolytes are given separately into the drip side-chamber when this contains 15% glucose or 4.3% glucose in 0.18% saline. Each electrolyte solution is administered separately (precipitation may occur when MgSO₄, K₂ HPO₄, and/or calcium gluconate are mixed together) and the 24-hour requirements of

FIG.—Introduction of infusates for complete intravenous feeding.

any one electrolyte solution are given in spaced doses; this reduces the danger of cardiac arrhythmias resulting from infusions of large amounts of calcium or potassium.

It is essential that the regimen should be written in detail on a treatment card, discussed with the nursing staff, and rewritten for each successive 24-hour period when the clinical and biochemical assessment for that particular day has been made. Plasma electrolytes, Astrup, and blood glucose estimations are performed daily, and plasma transaminase, calcium, phosphate, magnesium, haemoglobin, platelet, and white blood counts are done twice weekly. Drip set tubings and nutrient solutions are replaced every 24 hours. Millipore filters may be included in the circuit but they are not essential and their value in preventing sepsis is unproved; moreover, because of their small pore size, neither Intralipid nor blood can cross the filter. Holter silicone pumps are a useful means of maintaining constant infusion rates but are not essential.

Hypoglycaemia may follow abrupt termination of intravenous feeding. The mechanism is not clear, but it is possible that the infused glucose and/or amino acids may stimulate insulin release, and that high levels of circulating insulin persist after intravenous feeding has been discontinued. For this reason it is important to avoid abrupt termination of intravenous feeding. If possible, termination should be anticipated and oral feeding reintroduced a few days before discontinuing the infusion. During this period oral feeding is increased concurrent with the reduction of intravenous feeding. Frequent blood glucose determi-

nations are necessary during the transition from intravenous to oral feeding. Hypothermia may be a sign of severe hypoglycaemia.

D: Complications and their Prevention

The following complications may occur during intravenous feeding in infants: (1) septicaemia; (2) metabolic acidosis; (3) phlebitis and obstruction of peripheral and central veins; (4) catheter dislodgement with extravasation of fluid; (5) hypoglycaemia; (6) heart failure.

Some of these have already been mentioned and will therefore only be briefly discussed here.

(1) Septicaemia. The commonest infecting organisms are *Candida albicans*, *Staphylococcus aureus*, *Pseudomonas*, *Staphylococcus albus*, *achromobacter*, *Esch. coli*, and diphtheroids. Precautionary measures include the strictest of aseptic techniques both during the initial and subsequent procedures, daily changes of drip sets and nutrient solutions, avoidance of indwelling catheters (particularly in central veins) whenever possible, and removal of catheters in case of septicaemia. Where possible, regular blood cultures should be performed, and culture of catheter tips may assist in instituting appropriate antimicrobial therapy. The application of a topical antibiotic combined with nystatin or amphotericin B to the drip site may also be helpful, and the risk of infection when using central venous catheters may be further reduced by separating the site of entry of the catheter into the skin from that into the vein.

(2) **Metabolic acidosis.** Severe metabolic acidosis may be associated with the administration of hypertonic solutions containing high concentrations of fructose (Harries, 1971), and it is important to take the precautions already mentioned when such solutions are used.

(3) **Phlebitis and venous obstruction.** The frequency of phlebitis and venous obstruction in peripheral or central veins may be reduced by including isotonic fat emulsions, such as Intralipid, into the regimen. Intralipid and 15% glucose or Vamin can be given concurrently through a Y-shaped connecting tube. In order to avoid ascent of the lighter fat particles up the drip set tubing of the second infusate, the height of the Intralipid bottle above the floor should be considerably less than that of the second infusion bottle.

(4) **Catheter dislodgement with extravasation of fluid.** Catheter dislodgement with extravasation of fluid into adjacent tissues may occur when using superior vena cava catheters (Groff, 1969). Initial placement of the catheter into the superior vena cava is important, and its position should be confirmed radiologically; subsequent careful handling will reduce the risk of dislodgement.

(5) **Hypoglycaemia.** The prevention of hypoglycaemia has been fully discussed.

(6) **Heart failure.** Since most of the amino acid solution contains relatively high concentrations of sodium (Table I), careful calculations of sodium intake are necessary in order to avoid excessive intake, oedema, and cardiac failure. Several antibiotics also contain appreciable quantities of sodium (e.g. ampicillin and cloxacillin contain 3.0 and 2.0 mEq sodium/g injection, respectively).

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