Chapter 8

Nutritional Support in Pediatric Patients

Nutritionist assesses the patients that are not fed orally for 48 hours postoperatively, and the patients that are admitted to pediatric intensive care unit (PICU).

Following patients are at an increased nutritional risk:

1) Postoperative:

Post cardiac surgery and other major surgical procedures.

2) Cardiopulmonary disease:

Congenital heart defects, bronchopulmonary dysplasia, and cystic fibrosis.

3) Hyper metabolic states:

Major trauma, closed head injury, spinal cord injury, and sepsis.

4) Other conditions:

Short gut syndrome, inflammatory bowel disease, hepatic failure, muscular dystrophy, etc.

8.1 Protocol for Nutritional Support in Infants and Children

8.1.1 Nutritional Assessment

Dietary intake history: History of feeding problems, loss of appetite, recent weight loss, and relevant past medical history.

Physical Examination: Identify nutritional deficiency lesions.

Anthropometric measures: Weight, length, and head circumference for children < 3 years of age.

Laboratory tests: Serum chemistry-10, CBC, and total protein/albumin.

8.1.2 Set Nutritional Targets

The nutrional targets in a pediatric intensive care unit (ICU) patient are broadly divided into three stages to address the metabolic requirements of postoperative stress by adequate management of electrolyte and fluid intake, protein intake, and the calroc needs**.**

i) Stage I: It is a period during ICU day 1 to 2.

Fluid and electrolyte management during stage I is paramount.

It restore tissue perfusion and fluid balance.

ii) Stage II: It is a period during ICU day 3 to 10.

Metabolic resuscitation: Aim to limit protein catabolism and elevated glucose levels. Meet BEE (basal energy expenditure) with significant protein source, then progress to BEE × Stress factor (see *Table 8.1, 8.2*) as tolerated.

This phase may continue with moderate to severe infection beyond day 10.

iii) Stage III: It is day 8 to 10 and beyond. It is nutritional recovery and repletion phase.

During this phase aim full target nutrition and use BEE × injury factor or even higher using RDA table (see *Table 8.3*).

One might provide calories for catch-up growth once stress subsides and growth resumes during this stage.

8.1.3 Nutritional Targets in Malnourished Infants

Initiate nutrition by day #3. Achieve BEE × Stress factor by day # 5 to 6.

8.1.4 Nutritional Targets in Older Children and Infants with Good Nutritional Status

Initiate nutrition by day #3 to 5. Achieve BEE × Stress factor by day #5 to 8.

Table 8.1 **Basal Energy Needs for Infants and Children.*

Age 1wk to 10 months		**Age 11 to 36 months**			**Age 3 to 16 years**		
	Metabolic Rate		**Metabolic Rate**			**Metabolic Rate**	
Weight	**(kcal/day)**	**Weight**	**(kcal/day)**		**Weight**	**(kcal/day)**	
(kg)	**Male or Female**	**(kg)**	**Male**	**Female**	**(kg)**	**Male**	**Female**
3.5	202	9.0	528	509	15	859	799
4.0	228	9.5	547	528	20	953	898
4.5	252	10.0	566	547	25	1046	996
5.0	278	10.5	586	566	30	1139	1092
5.5	305	11.0	605	586	35	1231	1190
6.0	331	11.5	624	605	40	1325	1289
6.5	358	12.0	643	624	45	1418	1387
7.0	384	12.5	662	646	50	1512	1486
7.5	410	13.0	682	665	55	1606	1584
8.0	437	13.5	701	684	60	1699	1680
8.5	463	14.0	720	703	65	1793	1776
9.0	490	14.5	739	722	70	1886	1874
9.5	514	15.0	758	741	75	1980	1973
10.0	540	15.5	778	760			
10.5	566	16.0	797	782			
11.0	593	16.5	816	802			

* Adapted from the university of Virginia health system. Pediatric nutrition

Table 8.2 **Stress Factors.*

Clinical Condition	**Stress Factor**
Maintenance without Stress	1.0-1.2
Fever	12% per degree > 37 ℃
Routine/elective surgery, minor sepsis	1.1-1.3
Cardiac failure	1.25-1.5
Major surgery	1.2-1.4
Sepsis	1.4-1.5
Catch-up Growth	1.5-2.0
Trauma or head injury	1.5-1.7

* Adapted from the university of Virginia health system. Pediatric nutrition

Once clinically improved and beyond the critical phase of their illness (Day 7-10 and beyond), then RDA table (table 8.3) is used for determination of caloric and protein requirements. But due to limited activity, 70-90% of the RDA may be appropriate for children > age 3.

Table 8.3 **Recommended Dietary Allowances (RDA).*

	Age	**Weight**		**Height**		**Calories**	**Protein**	**Fluid**
	(years)	**(kg)**	**(lbs)**	**(cm)**	**(in)**	**(kcal/kg)**	**(gm/kg)**	**(mL/kg)**
Infants	0.0-0.5	6	13	60	24	108	2.2	140-160
	0.5-1.0	9	20	71	28	98	1.5	125-145
Children	1-3	13	29	90	35	102	1.23	115-125
	4-6	20	44	112	44	90	1.2	90-110
	7-10	28	62	132	52	70	1.0	70-85
Males	11-14	45	99	157	62	55	1.0	70-85
	15-18	66	145	176	69	45	0.8	50-60
Females	11-14	46	101	157	62	47	1.0	70-85
	15-18	55	120	163	64	40	0.8	50-60

* Adapted from university of Virginia health System. pediatric nutrition

8.1.5 Outcomes of Nutritional Therapy in the Pediatric ICU Patient

Nutritional therapy in a healthy or unstressed patient differs from nutrition in a stressed and hyper-metabolic patient. Induced metabolic stress and overfeeding may ↑ metabolic demands on the lungs and liver and may result in ↑ mortality.

Morbidity of overfeeding: It causes in excess CO_2 production, ↑ minute ventilation, pulmonary edema, and respiratory failure. It also causes hyperglycemia and ↑ infection rates. It induces lipogenesis due to ↑ insulin production, immunosuppression, and hepatic complications such as fatty liver and intrahepatic cholestasis.

8.1.6 Calorie and Protein Needs in Critically Ill Children

For determining protein and calorie needs of infants and children during critical illness, one should not use the standard RDA tables initially, to calculate energy requirements. Calorie and protein needs may be determined as follows:

Estimate basal energy needs (BEE), see Table 8.1.

Determine stress factor, see Table 8.2.

Total calories = BEE × Stress factor.

Patient's protein requirements: Total protein = Protein by RDAs × Stress factor (see Table 8.3).

Evaluate and adjust recommendations based on nutrition monitoring.

8.1.7 Alternate Methods of Estimation of Calorie Needs

The following alternate methods of determination of caloric needs in critically ill chidren are simple, and these methods can be readily applied.

(I) Simple Estimation of Calorie and Protein Needs in Infants and Children

One may use the following simple method of estimation of calorie and protein needs in infants and children (see Table 8.4).

Table 8.4 *Estimation of calorie and protein needs in infants and children.*

Age	Kcal/kg/day	Protéin gm/Kg/day
Preterm infant	120-140	3-4
Term infant-1yr	90-120	2-3
1-7 yrs	75-90	1-1.2
7-12 yrs	60-75	1-1.2
12-18 yrs	30-60	0.8-0.9
>18 yrs	25-30	0.8
>18 yrs	25-30	0.8

(II) WHO Recommendations (for Children > 1 Year)

According to the World Health Organization (WHO) the total energy needs for children > 1 year of age with critical illness is estimated by the following equation and using the table 8.5.

Total energy expenditure (TEE) =Resting energy expenditure (REE) × Stress factor.

Table 8.5 *Resting energy expenditure (for children > 1 year).*

Age in Years	Sex	REE
1-3 years	Male	60.9 × (W) −54
	Female	61.0 × (W) −51
3-10 years	Male	22.7 × (W) + 495
	Female	22.5 × (W) + 499
10-18 years	Male	17.5 × (W) + 651
	Female	12.2 × (W) + 746
18-30 years	Male	15.3 × (W) + 679
	Female	14.7 × (W) + 496

W = weight in Kg, REE= resting energy expenditure.

(III) Intravenous Calories For infants < 1 Year Age During Post Cardiac Surgery

Preterm infant: 90-110 kcal/kg/day.

Full term infant: (0-6 months) 90-100 Kcal/kg/day.

Older infant: (6-12 months) 80-100 Kcal/kg/day.

(IV) Seashore Formula

Basal energy needs (BEE) in critically ill children are estimated by Seashore formula as described below.

$$\text{BEE (Kcal/day)} = 55 - 2 \times \text{age in years}) \times \text{weight in Kg.}$$

Total daily energy needs = BEE + BEE (activity + maintenance + injury).

Activity 0.1-0.25, Maintenance 0.2, Simple trauma 0.2, Multiple trauma 0.4,

Sepsis 0.13 per degree > 37 ℃ rise in temperature, Burns 0.5-1, Growth 0.5

8.1.8 Caloric Needs in Adolescents and Adults

Harris-Benedict equation:

Men:

$$\text{BEE (Kcal/day)} = 66 + (13.7 \times \text{weight in Kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age in years}).$$

Women:

$$\text{BEE (Kcal/day)} = 65 + (9.6 \times \text{weight in Kg}) + (1.7 \times \text{height in cm}) - (4.7 \times \text{age in years}).$$

Total energy needs = BEE+ BEE (activity + disease / Injury factor).

Activity (bed rest 0.2, ambulatory 0.3), Simple injury 0.15-0.3

Severe infection / Multiple trauma 0.3-0.75, Burns 0.25 (10% burns) to 1.15 (70% burns).

8.1.9 Calculation of Catch-Up Growth

The full term infants and children with sub-normal growth due to chronic illness or malnourishment require additional calories and protein to achieve catch-up growth and these needs are added to the daily calorie requirements.

$$\text{Kcal/kg} = \frac{RDA\ (Kcal\ per\ Kg) for\ weig\ ht\ age\ ♦ \times \text{Ideal weight (Kg)}♥}{Actual\ \ weig\ ht}$$

♦ Age at which present weight is at the 50th percentile.

♥ 50th percentile for age or ideal body weight for height.

8.2 Total Parenteral Nutrition (TPN) in the PICU Patient

Patients who are unable to meet their nutritional needs via the oral or enteral route will require TPN. TPN should be started in infants or a previously malnourished by hospital day #3. TPN should be started in a previously well nourished children by hospital day #3 to 5.

8.2.1 Indications for TPN

Critical illness (trauma or sepsis) in the face of ileus or abdominal trauma.

Persistent GI intolerance / post-cardiac surgery.

Gastrointestinal (GI) anomalies and conditions.

Inflammatory bowel disease.

Short gut syndrome (during initial course of the disease).

Cancer in the presence of malnutrition and/or requiring intensive chemotherapy.

8.2.2 Initiation of TPN

The following nutrients and additives make up the solution of TPN at the initiation of orders.

(I) Dextrose

Recommended: 40-60% total calories, caloric value: 3.4 Kcal/gm.

Begin at 10-15% dextrose (depends whether the line is peripheral or central).

Advance by 2.5-5% per day in older infants and children until endpoint is reached.

Advance by 5-10% per day in adolescents until endpoint is reached.

Endpoint solution for peripheral TPN is DW12.5%.

Endpoint solution for central TPN is between DW 20%-25%.

Excess of carbohydrate calories results in adverse effects such as hyperglycemia, hepatotoxicity, cholestasis, glycosuria, and osmotic diuresis.

Insulin and TPN:

Insulin is often administered to treat hyperglycemia from stress or TPN.

The objective is to maintain serum glucose < 150 mg-200 mg/dL.

Add 1 unit of regular insulin per 10 grams of carbohydrate calories / or 75% of the prior day's sliding scale insulin dose to the TPN bag.

(II) Protein

Recommended non-carbohydrate protein calories: 15% of total calories.

Caloric value of protein: 4 Kcal/gm.

Requirement for protein:

Pre-term infant: 2.5-3.5 gm/kg/day. Full term infant: 2.5-3 gm/kg/day.

Infant < 1 year: 1.5-3 gm/kg/day. 1 to 10 years: 1-2 gm/kg/day.

11-18 years: 0.8-2 gm/kg/day.

Amino acid solutions:

Several solutions (Aminosyn, FreAmine, etc.) are available.

Solutions contain 3.5% to 10% solution and 5-15 gm of nitrogen per liter.

i) Nephramine 5.4%, contains essential amino acids plus histidine for renal failure patients.

ii) Hepatamine and FreAmine 8%, 6.9% contain high levels of branched chain amino acids for hepatic failure.

iii) TrophAmine: Used in infants < 1 years of age.

Provides essential amino acids, and amino acid profiles are within normal neonatal target range. Use of this solution ↓ cholestasis, and improves calcium and phosphorus solubility by ↓ pH of the solution.

Begin at 1.5-2 gm/kg per day and advance to endpoint goal by Day 2.

In renal insufficiency or renal failure, limit protein to 1.0 gm/kg/day on 1st day of TPN.

(III) Lipids

Recommended intake: 30-50% of total calories and 1-3 gm/kg/day (maximum 3.5 gm/kg/day).

Caloric value: Intralipid 10% = 1 Kcal/mL. Intralipid 20% = 2 Kcal/mL.

Begin at 1.0 gm/kg and advance by 1.0 gm/kg per day.

Endpoint goal: Infants: 3 gm/kg.

Children and adolescents: 1-2.0 gm/kg.

Endpoint depends on lipid clearance and age.

Essential Fatty Acid (EFA) Requirements:

Minimum dose: 0.5-1.0 gm/kg per day (20% Intralipid, 2 kcal/cc).

EFA deficiency state: Impaired wound healing, increased susceptibility to infections, thrombocytopenia, and flaky dry skin.

(IV) Electrolytes

The following are daily requirements of electrolytes in parenteral TPN.

Sodium: 2.0 to 6.0 mEq/kg/day or an average of 3.0 mEq/kg/day.

May add 2-4 mEq/Na^+ for each 100 mL of TPN solution.

Potassium: 2.0 to 6.0 mEq/kg/day or an average of 3.0 mEq/kg/day.

May add 2-4 mEq/K^+ for each 100 mL of TPN solution.

Chloride: 2.0 to 8.0 mEq/kg/day or an average of 4.0 mEq/kg/day.

May add 2-3 mEq/Cl^- for each 100 mL of TPN solution.

Calcium: 2.0 to 4.0 mEq/kg/day.

May add 0.5-2 mEq of Ca^{2+} for each 100 mL of TPN solution.

Phosphate: 1.5-3 mEq/kg / day.

May add 1.5-2.5 mEq of phosphate for each 100 mL of TPN solution.

Magnesium: 0.25-2.0 mEq/kg/day, or an average of 1.0 mEq/kg/day.

May add 0.3-0.5 mEq of Mg^{2+} for each 100 mL of TPN solution.

Daily Requirements for Calcium and Phosphorous:

The daily requirements for electrolytes such as calcium and phosphorous vary in infants and children to not only sustain growth but meet the metabolic needs of critical illness. The following are the recommendations for daily needs which varies with the age of the patient.

Table 8.6 *Requirements for calcium in mEq/kg/day.*

Preterm to term infants	Older children (10-40 kg)	Adolescents (>40 kg)
3.0-4.0	1.0-3	1.0-1.5

Table 8.7 *Requirements for Phosphorous in mEq/kg/day.*

Preterm to term infants	Older children (10-40 kg)	Adolescents (>40 kg)
3.0-4.0	1.0-3	1.0-1.5

The optimal Ca^{2+} to P^{2+} ratio for preterm and term infants is a 1 to 1.7:1 moles. The total of Ca^{2+} and P^{2+} cannot exceed 5.2 mEq/100 mL in standard amino acid solution, but can be 7.2 mEq/100 mL for TrophAmine.

(V) Trace Elements

Table 8.8 *Requirements of trace elements in TPN: (mcg/kg/day).*

	Pre-term	Term	Pediatric
Selenium	2	2	2 (maximum 30 mcg/day)
Zinc	300	300	100-300
Chromium	0.2	20	0.3
Manganese	2-10	2-10	2-10
Copper	20	100	20

The following solutions provide required trace elements:

Neonatal Trace-4 (for < 3 kg infant): 0.2 mL/kg/day.

Pediatric Trace-4 (for > 3 kg to 39 kg): 0.2 mL/kg/day (maximum 8 mL/day).

Other trace elements: Cobalt and iodine.

Trace elements and deficiency states:

i) Selenium: Selenocysteine is the biologically active form, and it is active site of enzymes involved in oxidation-reduction reactions. Protects against oxidant stress and ↑ immuno-responsiveness.

Deficiency: Muscle weakness and pain and cardiomyopathy; add this trace element if the patient is on TPN > 30 days.

ii) Copper: Component of metalloenzymes of iron metabolism, oxidative metabolism, free radical detoxification, and synthesis of hemoglobin, elastin, and collagen. Ceruloplasmin is an acute phase reactant and ↑ after infection, injury, or inflammation.

Deficiency: Anemias. Liver has significant copper stores, and deficiency occurs only after prolonged dietary abstinence.

iii) Chromium: chromium-containing glucose tolerance factor potentiates action of insulin.

Deficiency: Signs and symptoms similar to type 2 diabetes and cardiovascular disease.

iv) Manganese: Requirement is very low and even during prolonged TPN

Deficiency: Retardation of growth, skeletal and muscular abnormalities, and neurological signs.

v) Zinc: Component of metallo-proteins which control protein and nucleic acid synthesis.

Deficiency: Retardation of growth, hypogonadism, acrodermatitis, ophthalmic lesions, and deficiency in cell-mediated immunity.

(VI) Vitamins and Optional Additives

The following vitamins and the other additives are added to the TPN solution.

1) MVI (multi -vitamin injection), pediatric: MVI-12;

< 2.5 Kg infants: 2 mL/day. Children > 11 years: 10 mL/day.

> 2.5 Kg infants: 5 mL/day.

2) Vitamin K:

0.2 mg/day is added routinely when using MVI-12.

3) Optional additives:

a) Zantac: 1-2 mg/kg/day.

b) Iron: 0.1 mg/kg/day (maximum 2 mg/liter of TPN) for > 2 months of age.

c) Heparin: 0.5-1 unit/mL of TPN.

d) Insulin: 0.2 to 1 unit for 40 calories of carbohydrate.

e) L. Carnitine: 10-20 mg/kg/day for < 1.5 kg infant.

i) Physiology of Carnitine:

It is produced in liver and kidneys, and is stored in the skeletal muscles, heart, brain, and sperm. It is important for transport of long-chain fatty acids into mitochondria, a store house of energy.

ii) Carnitine deficiency and clinical observations:

Deficiency occurs by low dietary levels of the amino acids lysine and methionine, in certain genetic disorders, liver or kidney problems, and high-fat diets.

a) Carnitine and Shock:

Intravenous carnitine is helpful in treating shock from loss of blood, after a sizeable heart attack, or sepsis.

b) High cholesterol and carnitine:

↓ Total cholesterol and triglycerides, and ↑ HDL ("good") cholesterol levels.

c) Heart disease, CHF, and carnitine:

↓ likelihood of a subsequent heart attack or ↓ likelihood to develop CHF if it is given soon after a heart attack. It may help treat CHF, and improves exercise capacity in CHF.

d) Down's syndrome and carnitine:

L-acetylcarnitine improved visual memory and attention.

Colloid Supplements:

Albumin and blood may be administered early in severe hypoprotinemia and anemia.

The colloids only maintain (colloid) osmotic pressure, blood volume, and cardiovascular hemodynamics. The albumin’s half life is too-long to be used as a nutrient. Intravenous albumin spares body's labile proteins.

8.2.3 Advancement of Total Parenteral Nutrition

To meet the metabolic demands of the critical illness and achieve anabolic state and growth, the ingredients of the TPN solution are advanced as tolerated by the patient. The following are general recommendations for advancement of the TPN solution (see Table 8.9).

Table 8.9 *Advancement of total parenteral nutrition.*

Starting	Day 1-2	Day 3-4	Day 5-7
Protein (gm/kg),	1.5-2.0	2.0-3.5	Achieve end point.
Dextrose (%),	5-10%	10-15%	10-12.5%, IV peripheral 20-25%, IV central
Fat Emulsion (gm/kg),	1-1.5	2–3	Achieve set goal.

8.2.4 Writing of TPN Orders

1) Determine daily fluid requirement by weight and BSA:

In patients on total parenteral nutrition, it would underestimate fluid requirements by 12-15 mL/kg / day due to elimination of endogenous water production by orally given calories (see Table 8.3, dietary allowance of fluid).

In infants begin with infusion of 100 mL/kg / day for need of carbohydrate utilization rate of 0.4 to 0.9 gm/kg/hour (or 2-4 kcal/kg/hour), and infusion is increased to tolerance levels of 130-150 mL/kg /day.

2) Determine caloric requirements:

Refer to the above given formulae and tables for basal needs, stress factor, and for catch up growth.

3) Determine protein requirements:

Refer to the above formulae, stress factor, and growth factor.

Maintain non-protein calorie / nitorgen ratio of 150 to 200: 1

1 gm of Nitrogen is equivalent to 6.25 gm of protein.

4) Constitute appropriate solution:

Mixture of amino acid (Aminosyn) and / dextrose solution is to provide calories in a desired volume. Provide at least 30-40% total caloric need in the form of lipids daily, or lipid infusion may be given three times a week to provide essential fatty acids (EFA's).

5) Determine electrolyte requirements:

For calculation of daily requirements include content in amino acid solutions.

Provide adequate amounts of daily calcium and phosphorous.

It is crucial to maintain potassium balance: serum K^+ should be normal.

Potassium supplementation restores depleted intracellular stores and maintains positive nitrogen balance and anabolic phase, and glucose utilization is associated with intracellular movement of potassium. Glycosuria also results in obligatory renal loss of potassium and should be replaced. Intracellular movement of glucose and uptake (anabolism) require intracellular shift of potassium. Therefore, provide adequate K to prevent glycosuria and hyperglycemia before considering insulin infusions.

6) Add Trace elements and multivitamins:

Infants: Neonatal trace-4: (for < 3 kg): 0.2 mL/kg/day.

Infants and children: Pediatric trace-4 (for > 3 kg-39 kg): 0.2 mL/kg/day.

Note: Above formulary may not provide all required trace elements (see requirements above) Twice a week transfusion of plasma or albumin may also provide all essential trace elements.

7) Add Optional additives and Medications:

Zantac, regular insulin, iron, and carnitine. Iron may be added to infusion or iron stores are replenished with a blood transfusion.

8) Chose a solution:

TrophAmine (6% and 10%) contain crystalline essential and non-essential amino acids. All amino acids are of ("L"-isomer) except glycine.

Protein (gm/liter): 58 in 6% solution; 97 in 10% solution.

Nitrtogen (gm/liter): 9.3 in 6% solution; 15.5 in 10% solution.

Sodium (mEq/liter): 5 in 6% solution; 0 in 10% solution.

Acetate (mEq /liter): 54.4 in 6% solution; 97 in 10% solution.

Chloride (mEq /liter): < 3 in 6% solution; < 3 in 10% solution.

Osmolarity (m0sm/liter) 525 in 6% solution; 875 in 10% solution.

Illustrative calculation: TPN orders for a 12 kg 2 year old infant 72 hours post-cardiac surgery, on a ventilator support:

TPN Initial orders (day 1-day 2):

a) Total fluid volume: 1100 mL/24 hours (92 mL/kg).

Body weight method: (10 kg × 100 mL) + (2 kg × 50 mL) = 1100 mL/24 hours.

Note: above volume is underestimated by elimination of endogenous water production from orally ingested calories.

b) Basal energy needs (BEE) = 643 Kcal (table 8.1) (may also use alternate methods).

c) 30% of calories are provided in the form of 20% intralipid (96 mL).

Kcal (643) × 0.3) / 2 = 96 mL of 20% lipid (provides 1.6 gm of fat /kg bw).

20% Intralipid (20 gm/100 mL; 2 kcal/mL; 10% Intralipid (10 gm/100 mL; 1 Kcal/mL).

d) 70% of non-protein caloric intake is given in the form of 1004 mL of 13% dextrose.

Fluid remaining from total fluid allowance for a non-protein dextrose calories:
1100-96 = 1004 mL/24 hours.

Above volume may be reduced if net fluid balance is positive due to drug infusions.

Equation 1. (Kcal (643) ×0.7) / 3.4 = 132 gm.

Equation 2. (132 × 100)/1004 = 13% of dextrose.

(1 gm of dextrose yields 3.4 Kcal).

e) Initial protein given = 1.5 gm/kg = 12 ×1.5 = 18 gm in 12 kg infant

Equation 3. (18 × 100) / 1004 = 1.8% amino acid solution.

1004 mL of 1.8% amino acid and 12.7% dextrose provides needed calories and protein. This solution also provides additional protein calories = 18 × 4 = 72

TPN orders for (Day 3-10):

Fluid volume 115 mL-125 mL/kg (RDA table) / or fluid required (bw method) +15 mL/kg (for endogenous water metabolism) = 1280 mL

Total calories = BEE (643) × Stress factor (1.5) = 965 Kcal (may use alternate methods).

Provide 40% calories as Intralipid.

Total protein = Initial protein (18 gm) × Stress factor (1.5) = 27 gm.

or protein (RDA) (1.23 gm/kg) × stress factor (1.5) = 23 gm.

Use above mentioned calculations to give appropriate solution. as below:

Intralipid = (965 kcal × 0.4)/2 = 193 mL of 20% Intralipid / 24 hours (3.5 gm / fat /kg/day or 386 kcal)
20% Intralipid= (20 gm/100 mL; 2 kcal/mL).

Non-protein calories= 60% calories, in the fluid volume (1280− 193) = 1087 mL.

Equation 1. (965 kcal ×0.6)/3.4= 170 gm of dextrose.

Equation 2. (170 ×100)/ 1087 = 15.6% of dextrose.

Equation 3. (27 gm ×100)/1087 = 2.5% amino acid solution.

1087 mL of 15.6% dextrose and 2.5% amino acid solution /24 hours.

(Above solution provides additional protein calories, i.e., 27 ×4 = 108 kcal)

8.2.5 Monitoring of Patient on TPN

Daily weight and fluid balance.

Estimate fractional urine and blood sugar every 6 hours; daily serum electrolytes, BUN and creatinine, calcium, phosphorous, and magnesium until stable; then blood sugar, electrolytes, BUN and creatinine, Ca^{2+}, P^{2+}, and Mg^{2+} 2 - 3 times per week.

Once a week do a complete blood count, hepatic panel, and triglycerides. Do serum osmolarity, serum protein, and urine osmolarity weekly or occasionally.

8.3 Enteral Nutrition in Pediatric Critical Illness

8.3.1 Benefits of Enteral Nutrition

Trophic effects on the GI tract: Stimulation and maintenance of the gut mucosa.

Improved hepatic function compared to TPN, and simplifies fluid and electrolyte management.

Reduced metabolic and infectious complications.

Reduced incidence of pathogen entry / bacterial translocation into peritoneum or circulation.

Provision of at least 10-15% of caloric need as "trophic feedings" (enteric feeds) minimizes gut atrophy and potential for bacterial translocation and increased infection risk.

8.3.2 Selection of an Enteral Feed

Proper formula selection in a pediatric patient is influenced by:

1) Type of formula:

a) Osmolarity, renal solute load, caloric density, and viscosity,

b) Nutrient composition: Type and amount of carbohydrate, fat, and protein.

2) Patient's factors:

Age, diagnosis, nutritional requirements, and gastrointestinal function.

8.3.3 Continuous Tube Feeding

Usually begin at 0.5-1.0 cc/kg/hr, then progress as below:

Table 8.10 *Progression of continuous tube feedings.*

Weight (Kg)	Initial Infusion Rate	Daily Increases	Goal Rate
2-15	2-15 cc/hr	2-15 cc/hr q 4-8 hr	15-55 cc/hr
	or (1 cc/kg/hr)	or (1 cc/kg)	
16-30	8-25 cc/hr	8-16 cc/hr q 4-8 hr	45-90 cc/hr
	or (0.5-1 cc/kg/hr)	or (0.5 cc/kg)	
30-50	15-25 cc/hr	15-25 cc/hr q 4-8 hr	70-130 cc/hr
	or (0.5 cc/kg/hr)	or (0.5 cc/kg)	
> 50 kg	25 cc/hr	25 cc/hr q 4-8 hr	90-150 cc/hr

8.3.4 Intermittent Tube Feeding

Table 8.11 *Progression of intermittent tube feeding.*

Weight (Kg)	Initial Volumes	Daily Increases	Goal Volume
2-15	5-30 cc q 3-4 hr	5-30 cc q 6-8 hr	50–200 cc q 4 hr
12-30	20-60 cc q 4 hr	20-60 cc q 6-8 hr	150-350 cc q 4 hr
> 30	30-60 cc q 4 h	30-60 cc q 6-8 hr	240-400 cc q 4 hr

8.3.5 Composition of Commonly Used Enteral Feeds

Following tables (8.12, 8.13) summarize the substrate composition of commonly used enteral diets including their mineral content.

Table 8.12 *Relative composition of enteric formula / diets in Infants.*

	Milk,	**Similac**	**Similac-24**	**Isomil**	**Prosobee-24**	**Progestimil**	**Similac PM 60/40**
Cal /100 mL	67	68	80.6	67.6	81.1	68	67.6
Osmolarity	300	300	380	200	240	320	280
Carbohyd	6.8	7.3	8.5	6.9	8.2	6.8	6.9
Protein	1.0	1.4	2.2	1.7	2.4	1.9	1.5
Fat	4.0	3.65	4.25	3.69	4.3	3.8	3.78
Calcium	14	26.4	36.4	35.1	38	31.8	19
Phosphorus	9	18.8	36.5	32.9	38.9	28	12.3
Sodium	7.8	6.8	12.1	12.8	12.7	11.5	6.8
Potassium	13.5	18.2	27.4	18.9	25.2	18.9	14.9
Source of							
Carbohyd:	L	L	L	S/CS	CSS	D/CSS	L
Protein:	Mk	Nf Mk, Wh	Nf Mk	Sp	Sp	Casein Hydrol	Wh, cas
Fat:	Mk	Sa, So, Cn	So, Cn	So, Cn, Sa	Po, Su, Cn, So	Mct, Co, Su	Co, So, Cn

Carbohydrate, potein, and fat concentration in gm/100 mL, electrolytes in mEq/litre, osmolarity excpressed in mOsm/kg, Mk = milk, NfMk = non fat milk, L = lactose; CS = corn syrup, CSS = corn syrup solids, D = dextrose, S= sucrose, Cas = caseinate, Wh = whey protein, Sp = soy protein, Sa = saflower oil, So = soy oil, Co = corn oil, MCT oil, Cn = coconut oil, Su = sunflower oil, Po = palm olein. High levels of oleic acid are present in Sa, Su, and So.

Human milk, Similac: These are milk based formulae used to feed term and sick infants who are not in need of special nutritional requirements.

Similac-24: Milk formula, used in fluid restriction and for increased caloric demand.

Isomil: Indicated in milk intolerance and in lactase deficiency.

Prosobee-24: Soy formula indicated in fluid restriction and for increased caloric demand.

Progestimil: Indicated in infants requiring low molecular weight peptides or amino acids.

Similac PM 60/40: Useful in infants in cardiovascular / renal diseases benefiting from low mineral levels.

Table 8.13 *Relative composition of enteric formula / diets in children / adults.*

	Pediasure*	**Isocal+**	**Vivonex****	**Ensure Plus@**	**Vivonex Plus#**
Cal / mL	1	1.06	0.8	1.5	1.0
Osmolarity	335	270	360	690	650
Carbohyd	11	13.5	13	20.8	19.0
Protein	3.0	3.4	2.4	5.4	4.5
Fat	5.0	4.4	2.4	4.8	0.67
Sodium	17	23	17	43	27
Potassium	34	34	31	47	27
CH source:	Md, S	Md	Md, Ms	S, Md, CSS	Md, Ms
Protein	Cas, Wh	Cas, Sp	L amino acids	Cas, Sp	L-amino acids
Fat	Sa, So, MCT	So, MCT	MCT, So	Ca, Sa, Co	So

CS = corn syrup, CSS = cornsyrup solids, D = dextrose, S = sucrose, Md = maltodextrin, Cas = caseinate, Wh = whey protein, Sp = soy protein, Sa = saflower oil, So = Soy oil, Ca = canola oil, Co = corn oil, MCT oil, Ms = modified starch, CH source = carbohydrate source. Carbohydrate, potein and fat concentration in gm/100 mL, electrolytes in mEq/liter, osmolarity expressed in mOsm/kg.
* commonly used in children 1-10 years, + commonly used in adolescents / adults ** Elemental (modified protein) formula used in children, @ high caloric density formula used in adolescents / adults, # Elemental (modified protein) formula used in adolescents / adults

8.3.6 Modifying of Enteral Formula (Caloric and Nutrient Density)

Indications:

In children who are unable to take adequate formula volume to meet nutritional needs.

Modified formula provides greater caloric or nutrient density by following methods:

1. Increase concentration:

↑ the amount of formula base or decrease the amount of free water.

2. Supplementation:

Add following macronutrients to ↑ caloric density without increasing other nutrients:

1) Carbohydrate source:

Polycose liquid 2 cal/mL; Polycose powder 3.8 cal/gm (1 tbsp = 6 gm, 23 cal).

2) Fat source:

Microlipid 4.5 cal/mL, Vegetable oil 8 cal/mL, MCT oil 7.67 cal/mL (doesn't contain essential fatty acids).

3) Protein source:

Promod powder 4.2 cal/gm (1 tbsp= 4 gm).

Whole milk: 157 cal / 8oz, protein 8 gm/8oz, fat 8.9 gm/8oz, carbohydrate (lactose) 11 gm/8 oz.

8.3.7 Management of Complications of Tube Feedings

Nausea and Vomiting:

Maintain head of bed elevated and consider prokinetic medications.

Initiate tube feeding at low rates and advance slowly.

Consider alternate feeding routes i.e., duodenal/jejuna routes.

Constipation:

Increase free water intake, choose fiber containing formula, or add fiber or prune juice.

Diarrhea:

Switch to continuous feedings. Begin at slow infusion rate and advance slowly as tolerated. Reduce feeding rate to a previously tolerated rate, and advance more slowly as tolerated.

Use fiber containing formula or add fiber to the tube feeding.