Graph Model of Deciding the Combination of Total Parenteral Nutrition

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***Abstract*—Graph is a set of vertrices and edges. It could be used to model various problems related to any discipline. In this paper, some forms of graph are used to model the process of deciding the correct Total Parenteral Nutrition (TPN), an intravenous nutrition, which is dependent to the patient's physical condition and energy needs. Total Parenteral Nutrition is a various combination of protein, fat, and carbohydrate, which will be delivered directly into the blood system.**

***Keywords*—Graph Modelling, Nutrition Calculation, Total Parenteral Nutrition.**

I. Introduction

Humans need energy to live their lives. The energy we needed could be obtained from nutrients. The nutrients required in our body have different functions and, therefore, different quantities. The nutrients we needed also vary between individuals, depending on various factors such as age, gender, height, weight and activity.

The nutrients we need primarily (macronutrients) consist of carbohydrate, protein, and fat. These nutrients could be obtained by consuming food. Foods are then broken down into smaller components in our digestive system, so our body could absorb them and then distributes the nutrients via our blood system.

The nutrients we needed are digested in different places. Carbohydrates are digested along the digestive system into monosaccharide, proteins are digested in the stomach and duodenum into amino acids, and fats are mainly digested in the small intestine into fatty acids. These digested nutrients are the ones that will be absorbed in the intestine. This is how we get our nutrition in our daily life, but what if we couldn't/shouldn't put our intestines to work?

Some conditions such as severe illness, major surgery, and gastro-intestinal surgery are contraindication for normal feeding, but such conditions put our body into higher needs of nutrients. Deficit of nutrients will cause a deterioration, so other way of feeding should be considered.

Total Parenteral Nutrition (TPN) is an intravenous nutrition. TPN provides all or most of the required calories and nutrients for the patient. The solution contains protein, carbohydrates, glucose, fat, vitamins, and minerals.

Parenteral nutrition is used for patients who are malnourished or at risk of malnutrition and has a non-functioning or inaccessible gastrointestinal (GI) tract, preventing enteral feeding. TPN is used for these patients because it's delivered directly through the vein, so they could obtain nutrients without enteral feeding.

In reality, micronutrients, such as vitamins and minerals, are also important to maintain the metabolism process; therefore it should also be considered especially in severe illness. However, it is very complex too calculate and in most prepared solutions, the micronutrients are almost always included. So then, calculating the macronutrients will be enough to prepare TPN.

II. Calculating Nutrients

As mentioned before, every individual have different amount of nutrients they need. To do this, we need to first calculate the amount of energy the patient needed. Energy needs are calculated with the Harris-Benedict (sedentary) based on Basal Metabolic Rate (BMR) × Injury Factor × Activity Factor [6]:

Female [4]-[6]:

$$BMR = 655 + (9.6 \times weight) + (1.8 \times height) - (4.7 \times age)$$

Male [4]-[6]:

$$BMR = 66 + (13.7 \times weight) + (5 \times height) - (6.8 \times age)$$

Harris-Benedict (sedentary) [5]:

$$BMR \times 1.2$$

Injury Factors [6]:

- 1.0 - Normal, Minor Surgery
- 1.2 - Long Bone Fracture
- 1.0-1.2 - Burn Post Graft
- 1.3 - COPD, Malnourished
- 1.4 - Severe Head Injury
- 1.5 - 50% Burns
- 1.0-1.5 – Cancer
- 1.6 – Ventilator

1.2-1.6 - Major Surgery, Multiple Trauma, 0-20% Burns Pre Graft
1.2-1.7 - Acute Sepsis
1.5-2.0 - 20-40% Burn Pre Graft
2.0 - 50% Burn.

Activity Factor [6]:
1.1 for each °C > 37°C.

Note: Weight in kilos, height in cm, and age in years.

Next, to administer TPN, calculate the amount of fluid needed. The amount needed ranges about 30-50 cc/Kg of body weight, but severe catabolic state requires up to 100 cc/Kg for the patient.

Thirdly, we need to determine the protein needs. The protein required is estimated using two methods. The first method is by using the total energy (Kcal) to nitrogen (N) ratio. The ratio in stressful condition is 100-150 Kcal: 1 gm, and 250-300 Kcal: 1 gm N for normal condition. The second method uses the overall needs which starts from 0.83 g/Kg and add stress and other factors as needed. The common needs of protein are about 1.2 g/Kg.

Table 1. Amino Acid Solutions [7]

Percent Solution	***AA Content** (g/100 mL)*
3.0%	3.0
3.5%	3.5
5.0%	5.0
7.0%	7.0
8.5%	8.5
10.0%	10.0

After that, we need to calculate the amount of fat required. Currently, only 10%, 20%, and 30% fat emulsion are available, each contains 1.1 Kcal/cc, 2.0 Kcal/cc, and 3.0 Kcal/cc respectively. The essential fatty acid (EFA) should also be calculated. The EFA required about 2-4% of total energy and 1-2.5 g of fat/Kg.

Finally, determine the amount of carbohydrate required which in TPN, provided as dextrose monohydrate. One of the common solutions of dextrose is the D50W, which contains 50% dextrose, providing 3.4 Kcal/g of dextrose.

Table 2. Dextrose Solutions [7]

Percent Solution	**Dextrose (g/100mL)**	**Notation**
5%	5	D_5W
10%	10	$D_{10}W$
20%	20	$D_{20}W$
30%	30	$D_{30}W$
40%	40	$D_{40}W$
50%	50	$D_{50}W$
60%	60	$D_{60}W$
70%	70	$D_{70}W$

III. GRAPH THEOREM

Graphs consist of vertices and edges which connect these vertices. The vertices represent discreet objects, while the edges represent the relationship between vertices. There are six different kinds of graphs: simple graph, multigraph, pseudograph, simple directed graph, directed multigraph, and mixed graph, each differs depending on whether edges have directions, whether multiple edges can connect the same pair of vertices, and whether loops are allowed.

Table 3. Graph Terminology [8]

Type	**Edge**	**Multiple Edges Allowed?**	**Loops Allowed?**
Simple Graph	Undirected	No	No
Multigraph	Undirected	Yes	No
Pseudograph	Undirected	Yes	Yes
Simple Directed Graph	Directed	No	Yes
Directed Multigraph	Directed	Yes	Yes
Mixed Graph	Directed and Undirected	Yes	Yes

Some terms that are commonly used related to graphs are adjacent, incident, degree, path, and circuit. Adjacent is a condition when two vertices are connected by the same edge and such edge is called incident with both vertices. Degree is the sum of different edges that are connected to a vertex. A path is a sequence of edges, starting from a certain vertex, which travels along edges connecting several adjacent vertices. A circuit is formed when at least three vertices form a path which begins and ends with the same vertex.

Graph models could be used in many problems related to any discipline of knowledge. For instance, graphs could be used to represent an electric circuit, to represent the telephone networks, or to represent the process to build a house.

Another model of graph is the tree. Trees are connected graphs without any circuit, so called because such graphs resemble trees. For example, graphs that are used to represent binary searching charts are called binary search trees. Binary search trees use vertices to represent the value of an element and edges to represent value difference relationships, for example the right side edge means the next element is lesser than its predecessor and the left side edge means the next element is greater than its predecessor.

Some applications of trees sets a particular vertex of a tree is as the root. From that root, we could assign a direction to each edge to connect its children. Each path formed is unique, because each leaves have its own path to the root in the graph. This type of tree is called a rooted tree.

One of the uses of rooted trees is to model problems in a series of decisions leads to a certain solution. For example, a binary search tree locates an element by comparing the searched element with the current root, if it is not the element we're looking for, then determine, as previous example, whether we should go right or left in a subtree. A rooted tree in which each internal vertex corresponds to a decision, with a subtree at these vertices for each possible outcome of the decision, is called a decision tree [8].

IV. DECIDING TPN COMBINATION

To decide the right solutions to administer, we must consider the amount of fluid required by the patient. The amount of fluid given to the patient is very important, because it affects the kidney's performance and it's ability to maintain the blood volume. The amount of fluid are also restricted by the rate of fluid delivery. Solutions with low concentration contain more fluid than solutions with higher concentration with the same amount of solute. Therefore, it's highly unlikely to use multiple solutions with low concentration for each nutrient.

The concentration is also important because it correlate with its molarities. High molarities solution cannot be delivered through peripheral vascular; it should be delivered through central vascular which is more difficult to be prepared.

Other consideration is the cost. Higher concentration solutions are more expensive.

There are 144 possible combinations of solutions to be used in TPN.

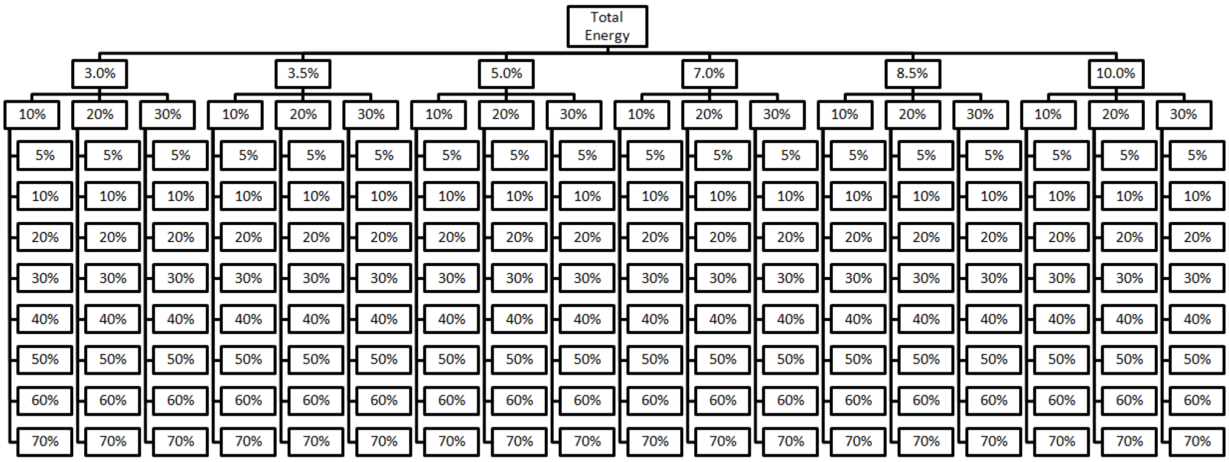

Figure 1. TPN Combinations Tree

Notes: First level: available protein solutions, second level: available fat solutions, third level: available carbohydrate solutions.

However, to decide the right combination, we need to calculate the amount of fluid of the solution we use and compare it with the amount of fluid the patient should take. If it's too close to the amount required, consider choosing the next solution(s) to be of high concentration or changing earlier solutions.

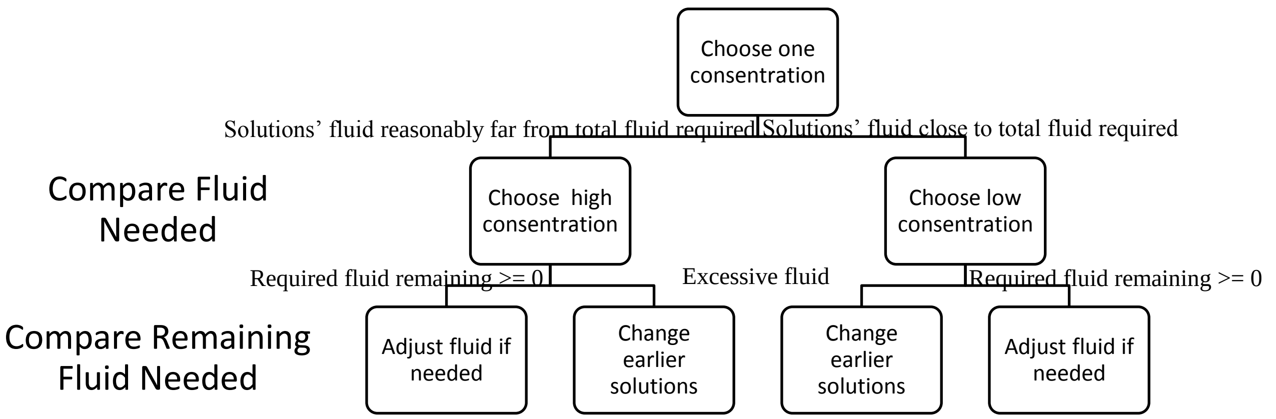

Figure 2. Choosing the right solution

For a 43 years old male patient with 70 kg body weight and 170 cm height who underwent gastro-intestinal surgery, we can calculate the calorie needed:

$(66 + 13.7 \times 70 + 5\times 170 - 6.8 \times 43) \times 1.2 \times 1.2 =$

2,278.9 Kcal/day

Fluid needed:
$30 \times 70 = 2{,}100$ cc/day to
$50 \times 70 = 3{,}500$ cc/day

Protein needed :
$1.5 \times 70 = 105$ g/day, which is equal to
$105 \times 4 = 420$ Kcal/day

The amount of fat needed:
$70 \times 1.0 = 70$ g/day to
$70 \times 2.5 = 175$ g/day, which is equal to
$70 \times 9 = 630$ Kcal/day to
$175 \times 9 = 1575$ Kcal/day

So far, the calorie needed by the patient is about 1050-1995 Kcal/day, which means the calorie from carbohydrate will be around 283.9-1,228.9 Kcal/day which is equal to 70.9-307.2 g.

The amount of fluid provided by protein solutions:
3.0% = 3,500 cc
3.5% = 3,000 cc
5.0% = 2,100 cc
7.0% = 1,500 cc
8.5% = 1,200 cc
10.0% = 1,050 cc

Since the fluid needed is around 2,100-3,500 cc, it would be more reasonable to choose a 10% protein solution.

The amounts of fluid provided by fat solutions:
10% = 700-1,750 cc
20% = 350-875 cc
30% = 233-583 cc

So far, the amount of fluid needed remaining 1,050-2,450 cc. The minimum carbohydrate requirement, theoretically, is 100 g/day, which is equal to 1000 cc of 10% solution. But after some calculations, we could find that 10% carbohydrate is not ideal. So, we choose 20% carbohydrate and 400 cc of 20% fat solution. As the result, the TPN combination will be 10% protein solution, 20% fat solution, and 20% carbohydrate solution.

Table 3. TPN Combination Result

	Solution	Σ Fluid (cc)	Calorie (Kcal)
Protein	10%	1050	420
Fat	20%	400	720
Carbohydrate	20%	1550	1240
Total		3000	2380

So to find the right combination, we need to do the following process.

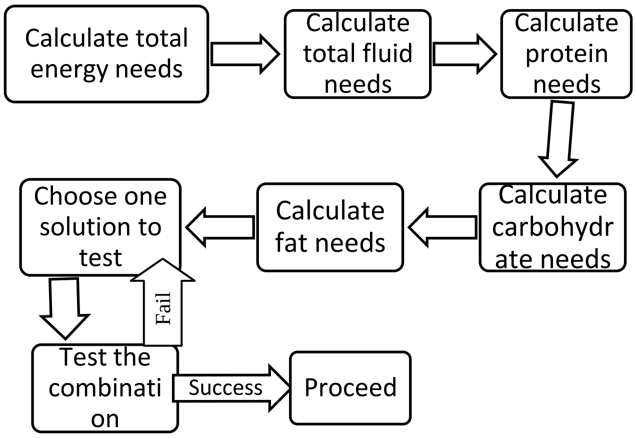

Figure 3. Deciding TPN Combination

V. Conclusion

To provide the right amount of nutrients combination, the tree is needed to avoid intake imbalance. However, the knowledge of daily intake requirements and the consideration of the patient's condition should be mastered.

TPN provides an alternative to enteral feeding for those who are currently unable to put their intestines to work. Administering TPN, however, needs extra care compared to enteral feeding to prevent complications.

In certain conditions, micronutrient content should be carefully calculated, but generally calculating macronutrients is enough. With trials and errors, several recalculations might be necessary to find the correct combination for the TPN.

VI. Appendix

A. *Reference Card* [6]

Reference Cards

Critical Care Nutrition

Calculations of Caloric and Protein Requirements (index)

Caloric Requirements = Harris Benedict Eqn(a) X Injury Factor X Activity Factor

- **Males***: 66.5 + (13.7xWt. in kg) + (5.0 x Ht. in cm) - (6.8 x age in Yrs.)
  Females*: 655 + (9.6 x Wt in kg) + (1.8 x Ht in cm) -(4.7 x age in Yrs.)
  *Daily Basal Energy Estimate Expenditure
- **Injury Factors**: **1.0** - Normal, Minor Surgery; **1.2** - Long Bone Fracture; **1.0-1.2** - Burn Post Graft; **1.3** - COPD, Malnourished; **1.4** - Severe Head Injury*; **1.5** - 50% Burns; **1.0-1.5** - Cancer; **1.6** - Ventilator*; **1.2-1.6** - Major Surgery, Multiple Trauma, 0-20% Burns Pre Graft; **1.2-1.7** - Acute Sepsis; **1.5-2.0** - 20-40% Burn Pre Graft; **2.0** - 50% Burn.
- **Activity Factor**: **1.1** for each °C > 37°C.

Daily Total Energy Expenditure Estimation: Normal Maintenance: 25-28 kcal/kg; Mild-Moderate stress: 30-35 kcal/kg; Severe major stress 40 kcal/kg; Adult Burn: Maintenance + 40 kcal/% burn.

Macronutrient (Carbohydrates, Fat, Protein) Requirements
Glucose: 30-70% of total daily caloric intake, or 2-5 g/kg/day.
Fat: 15-30% of total daily caloric intake; <= 0.1 g/kg/hr
Protein or Amino Acids: 15-20% of total daily caloric intake. Estimation per IBW → Maintenance, unstressed - 0.80-10 g/kg; Anabolism, moderate stress - 1.2-1.5 g/kg; Infection, major surgery - 1.3-1.6 g/kg; Major trauma, sepsis, burns - 17.5-2.0 g/kg.

Caloric Estimate of Fuel Sources - IV Dextrose - 3.4 kcal/g; Enteral CHO - 4.0 kcal/g; Fat - 9 kcal/g; Protein - 4 kcal/g.

Non Protein Caloric Requirements - Enteral: Carbohydrates: 70-80%; Fat: 20-30%; Non Protein calories: N →100 : 1 - 150 : 1 (Note 6.25 g of protein = 1 g of Nitrogen); TPN: Carbohydrates: 50-75%; Fat: 20-50%; Non protein calories: N →125:1 - 200:1.

B. Estimated Average Requirements for Energy [9]

EAR - MJ/day (kcal/day)

Age	Males		Females		Age	Males		Females	
	(MJ)	(kcal)	(MJ)	(kcal)		(MJ)	(kcal)	(MJ)	(kcal)
0-3 mo	2.28	(545)	2.16	(515)	11-14 yr	9.27	(2220)	7.72	(1845)
4-6 mo	2.89	(690)	2.69	(645)	15-18 yr	11.51	(2755)	8.83	(2110)
7-9 mo	3.44	(825)	3.20	(765)	19-50 yr	10.60	(2550)	8.10	(1940)
10-12 mo	3.85	(920)	3.61	(865)	51-59 yr	10.60	(2550)	8.00	(1900)
1-3 yr	5.15	(1230)	4.86	(1165)	60-64 yr	9.93	(2380)	7.99	(1900)
4-6 yr	7.16	(1715)	6.46	(1545)	65-74 yr	9.71	(2330)	7.96	(1900)
7-10 yr	8.24	(1970)	7.28	(1740)	74+ yr	8.77	(2100)	7.61	(1810)

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STATEMENT

I hereby declare that I wrote this paper are my own writing, not adaptation, or translation of papers of others, and not plagiarism .

Bandung, 11 December 2014

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