Nutritional Support in Intensive Care Unit (ICU) Patients

Topic 18

Module 18.3

General Principles of Prescription and Management

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Learning Objectives

- Key criteria to start nutrition support;
- Assessment of nutritional status;
- Situations where early enteral nutrition was shown beneficial;
- Optimal timing and amount of nutrition support;
- Prevention and management of the common complications of nutrition support.

Contents

Key Messages

- Increased requirements during critical illness must be matched by appropriate infusion of calories and nitrogen, especially when severe malnutrition is present, in case of insufficient oral intake or expected delay before recovery of eating;
- Early enteral nutrition can be systematically considered in patients unlikely to recover their ability to eat within 48 hours after injury;
- Nutritional status can be assessed from physical and biological variables combined in scores;
- Inappropriately high amounts of energetic substrates can lead to detrimental effects, especially after a long period of fasting;
- The use of local algorithms and protocols is recommended to optimize nutrition support.

1. Criteria for implementation of nutritional support

In general terms, the increased energetic and protein requirements during critical illness must be matched by appropriate infusion of calories and nitrogen. Therefore, the implementation of nutritional support in a critically ill patient is obviously indicated when at least one of the three following criteria is present:

- Pre-existing severe malnutrition
- Oral intake matches < 50% of the energy and nitrogen needs
- Expected delay before recovery of eating > 5-7 days

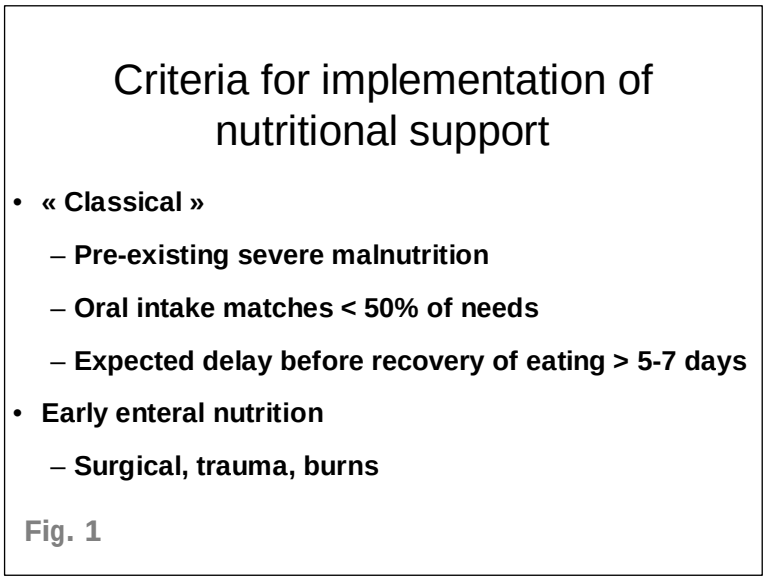

Fig. 1

In addition to this approach, surgical, trauma (including burns) benefit from enteral nutrition started within 48 hours following injury, as confirmed by several studies who demonstrated consistent benefits in terms of decrease in septic morbidity, hospital and ICU length of stay and mortality (1, 2).

The absence of gut feeding, or gut starvation, may represent an important trigger for systemic infections due to typically gastro-intestinal micro-organisms. Numerous disturbances found at different levels of the gastrointestinal tract have been advocated and summarized in Fig. 2.

Adverse effects of starvation

Gut barrier (epithelial cell junction)	Increased permeability to macromolecules and micro-organisms (bacteria, fungi)
Enterocytes	Increased adherence of bacteria
Intestinal flora	Overgrowth of pathogens
Sub-mucosal immune system	Atrophy of Peyer's patches Decreased production of immunoglobulin A

Fig. 2

Accordingly, early enteral nutrition is a common practice in intensive care units (3) and is recommended in several circumstances where it has been proven useful (see the algorithm shown on Fig. 1). This algorithm is consistent with others recently updated recommendations (3, 4, 5,).

1.1 Nutritional status

Although the assessment of the current nutritional status is an important issue in ICU patients, it may be difficult to estimate precisely with methods validated in other settings, using anthropometric or biological variables and functional tests (muscle and immune function) to generate a risk score (for instance Subjective global assessment SGA (6), MUST (7) Nutritional Risk Index (NRI (8)), MNA (9), PINI (10).

Importantly, these scores have been designed and validated in patients with chronic illnesses, but not in acutely ill patients, in whom several features will influence the assessment. The PINI score is the only one in whom the inflammatory status (C-reactive protein and orosomucoid) was included.

Table 1 SCORING SYSTEM

Anthropometry

Body mass index	18.5-25 kg/m^2	17.0-18.5:mild (gradeI) 16.0-16.9:mild to moderate(gradeII) 13.0-15.9:moderate(grade III) 10.0-12.9:severe(grade IV) <10.0:very severe(grade V)
Waist:Hip ratio	<0.8	-
Tricipital skin fold thickness	Male:12mm Female:25mm	<6mm <12mm
Mid-arm muscle area	Male:55cm^2 Female:31cm^2	<38.5cm^2 <20cm^2

Lean body mass ~=

$$\frac{\left\{\text{mid-arm circumference (cm)}\left(0.314\times\left[\begin{array}{c}\text{triceps skinfold}\\ \text{thickness (mm)}\end{array}\right]\right)\right\}}{4\pi}-\left(\begin{array}{c}10\text{ [males] or}\\ 6.5\text{ [females]}\end{array}\right)$$

Fig. 3

Biochemistry

	Normal range	Malnutrition value	Half-life (days)	Molecular weight (Da)	Influence of inflammatory status
Albumin	35-50 g/l	<30 g/l	20	66 000	++
Transthyretin	45-70 mg/l	NA	2	55 000	+++
Transferrin	2.0-3.5 g/l	NA	8.8	80 000	++

Fig. 4

Muscular / immune testing

Variable	Normal value	Malnutrition value
Muscular mass		
Mid-arm muscle area	Male:55 cm^2 Female:31cm^2	<38.5cm^2 <20cm^2
24-hour creatinine	Male: Ideal body weight x 23 Female: Ideal body weight x 18	<80% normal value
Immune function tests		
Cutaneous tests of delayed hypersensitivity	Present	Abolished or severely impaired
Lymphocyte count	<3000/mm^2	<1200mm^2

Fig. 5

2. Timing

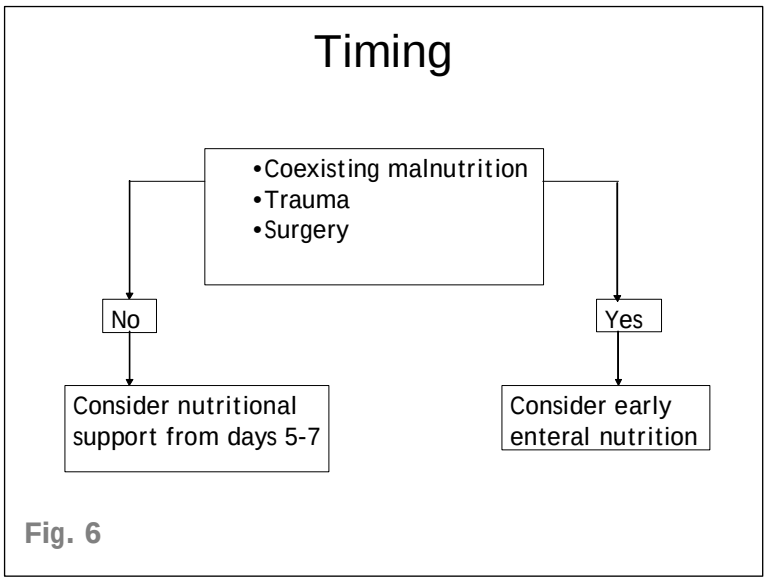

Fig. 6

This issue requires the assessment of possible benefits from early (< 48 h) enteral nutrition. If the patient is not likely to benefit from early enteral nutrition, delayed artificial nutrition (preferentially enteral) or parenteral should be instituted when the patient did not recover the ability to cover his caloric and protein requirement for 5-7 days (see discussion in the "choice of route" module18.4).
In contrast, no benefit has been associated with an early implementation of parenteral nutrition in critically ill patients (11, 12).
The parenteral route should be reserved only when the gastro-intestinal function does not allow the administration of enteral nutrition, or when the tolerated amount of enteral meets less than 50% energy requirements over a prolonged period.

3. Amount

Amount (N losses)

	Principle	**Interpretation**
Nitrogen balance	**Input** [(proteins, amino acids)x0.13] – **Output** [Urinary urea x0.036]	0 –: catabolism +: anabolism
Plasma [Phenylalanine]	Circulating level = muscular synthesis	Reflects protein breakdown
Urinary 3-methylhistidine	Muscular release of non-reusable amino acid	Reflects the protein breakdown
Stable isotopes	Rate of appearance of radiolabelled amino-acids Associated with muscular biopsies	Rate of protein breakdown and synthesis Fractional synthesis rate

$$\text{Nitrogen loss (g/24 h)} = \frac{\text{Daily diuresis (L)} \times \text{daily urinary urea excretion (g)} \times 1.2}{2.14}$$

Fig. 7

The amount of artificial nutrition to be supplied is based on the requirements of energy, nitrogen and micro-nutrients.
In general terms, the caloric expenditure and the loss of nitrogen are increased during critical illness.
The actual values of the resting energy expenditure can be estimated by direct measurements or predictive equations (see unit 1 of this module).

Comparative studies indicate that the equations can be used as a reliable estimate even though they do not allow an accurate evaluation of the energy expenditure.
The nitrogen losses can be estimated by direct measurements of nitrogen metabolism (Fig. 7).

Although the direct measurements and if not available the predictive equation allow an individual estimation of the patients' needs, the resting energy expenditure and nitrogen requirements of most critically ill patients fall within the following range :

RESTING ENERGY EXPENDITURE:

Females: **25-30 kcal/kg.day**

Males: **30-35 kcal/kg.day**

NITROGEN LOSSES

0.2-0.25 g/kg.day

The provision of a too large amount of calories can lead to deleterious effects, related to hyperglycemia, inflammatory response, to increased carbon dioxide production and to liver dysfunction. (13).
Remarkably, the provision of an amount of calories calculated to match exactly the resting energy expenditure in severely malnourished patients can also lead to a similar situation, known as "refeeding syndrome".
This syndrome, reported in hunger-strikers and in war prisoners, is associated with disturbances of body-fluid distribution, abnormal glucose and lipid metabolisms and severe electrolyte abnormalities (mainly hypophosphatemia, hypokaliemia and hypomagnesemia).
The pathogenesis of this potentially life-threatening syndrome involves the sudden shift from fat to carbohydrate metabolism, leading to sudden intracellular glucose loads and increased insulin release (14).

Fig. 8

Amount (energy)

Method	Principle	Conditions for use
Calorimetric methods		
▪Direct calorimetry	Determination of heat produced	Closed environment (entire body in a closed chamber)
▪Indirect calorimetry	O_2 consumption,CO_2 production, nitrogen excretion	Ventilation,fraction of inspired oxygen(FiO_2)<0.6
Non-calorimetric methods		
▪Isotopic (doubly-labelled water)	CO_2 production estimated from the difference between labelled hydrogen and labelled oxygen	-
▪Fick method	Cardiac output x Difference in oxygen contents between arterial and mixed venous blood	Pulmonary artery catheter
▪Physical activity	Pedometer, accelerometer	Not suitable for ICU patients
▪Muscular activity	Electromyography	Not assessed in ICU

4. Composition of nutrition support formulas.

During isocaloric nutrition, glucose is a preferential substrate in most critically ill patients: it should cover 70-100% of non-protein energy supply (15).
The rate of glucose supply should not exceed 4 mg/kg per min, to avoid the activation of de novo lipogenesis pathway and the associated increased pulmonary CO_2 excretion.
It is recommended to provide 15 – 30% of non protein energy as lipids, except in patients with acute ischemic heart diseases, major burns and severe infection, in whom fat supply should be reduced.

COMPOSITION OF ENTERAL AND PARENTERAL FORMULAS

Basic difference between enteral and parenteral solutions

	Enteral	Parenteral
Composition	Ready for use	Components to be mixed
Nitrogen	Intact proteins(animal or vegetable origin) Semi-elemental or elemental	Free amino acids Dipeptides
Carbohydrates	Polymers of monosaccharides (glucose, fructose, xylitol, sorbitol): maltodextrins and starches	Hypertonic glucose
Vitamins + trace elements	Already incorporated	To be added
Osmolarity(range)	200-480mOsm/L	700-1200mOsm/L

Fig. 9

Protein supply should cover 15-20% of total energy supply, or 1.5 – 2.0 g/kg per day.

4.1 Basic components

The basic composition of the solutions used for nutritional support is similar whatever the route of administration: the caloric supply is shared between carbohydrates, lipids and proteins (Fig. 10).

The non-protein caloric/nitrogen ratio is an index of the efficiency of the solution, with the highest rate (ideally < 150 kcal/gN) associated with a maximal use of energy for protein anabolism.

However, there are several fundamental dissimilarities between the two types of solutions, as shown by the comparison of the usual ranges of the components in ready-for-use solutions (18).

COMPOSITION OF ENTERAL AND PARENTERAL FORMULAS

Enteral solutions.
Energy content: isoenergetic (1 kCal/ml) or high energy (1.2 to 1.5 kcal/ml)
Nitrogen content: 15 to 18% of the total energy supply or high protein: more than 20% energetic supply.
Fibers: To release short chain fatty acids, a main fuel for colonocytes, and to decrease diarrhea incidence. The end product of the fermentation is butyrate, propionate or acetate.
Parenteral solutions.
Energy content : Glucose, triglycerides (0.6-1.0 kcal/ml)
Nitrogen content : free aminoacids

Fig. 10

The initial choice of a nutritional support formula is easy when basic questions are answered (19, 20).

For most patients, at the present time, standard iso-energetic fiber-free enteral solutions, or basic ternary parenteral solutions are reasonable choices although the recommendation of some specialized formulas as a first-line support is possible in the near future.

4.2 Additional components

In contrast to enteral feeding formulas, parenteral nutrition does not contain trace elements nor vitamins. Therefore, these components must be added daily when the patient is only nourished parenterally. Several available solutions of trace elements and vitamins comply with current recommendations of daily intake.

Table 2 Current recommendations of daily intake

	Enteral	**Parenteral**	**PRI**
Caloric content	1000-1400 kcal	800-1200 kcal	1800-3200 kcal
Macronutrients			
Carbohydrates	120-185 g	120-160 g	55% of energy
Lipids	15-68 g	30-45 g	30% of energy
Proteins	37-94 g	31-44 g	40-100 g
Micronutrients			
Minerals			
Sodium	560-1380 mg (13-32 mEq)	0-6500 mg (0-150 mEq)	575-3500 mg
Potassium	1000-2630 mg (26-68 mEq)	0-5800 mg (0-150 mEq)	2000-4000 mg
Chloride	850-1740 mg (24-49 mEq)	0-4250 mg (0-120 mEq)	750-4600 mg
Calcium	530-1200mg	0-10 mEq	1000 mg
Phosphorus	535-1700 mg	0-45 mEq	1000 mg
Magnesium	200-425 mg	0-20 mEq	400 mg
Trace elements		Not included	
Iron	8.9-24 mg		10 mg
Zinc	10-36 mg		15 mg
Copper	1.1-3.4 mg		1.5 mg
Manganese	1.7-6.3 mg		2 mg
Fluorine	0-1.5 mg		1.5 mg
Molybdenum	0-220 μg		75 μg
Selenium	0-140 μg		70 μg
Chromium	0-140 μg		50 μg
Iodine	75-200 μg		150 μg
Vitamins			
A	2331-12000 IU		2000(F)-2666(M) IU
β-carotene			
B1 (thiamine)	1.3-3.2 mg		1.1(F)-1.3(M) mg
B2 (riboflavin)	1.5-3.6 mg		1.5(F)-1.6(M) mg
B5 (panthothenic acid)	4.7-22 mg		5 mg
B6	1.5-4.3 mg		2 mg
B8 (biotin)	40-635 μg		300 μg
B9 (folic acid)	200-850 μg		400μg
B12	2.1-13 μg		6 μg
C	67-1000 mg		60 mg
D	200-520 IU		400 IU
E	19-317 IU		30 IU
K	43-127 μg		80 μg
PP	16-43 mg		20 mg

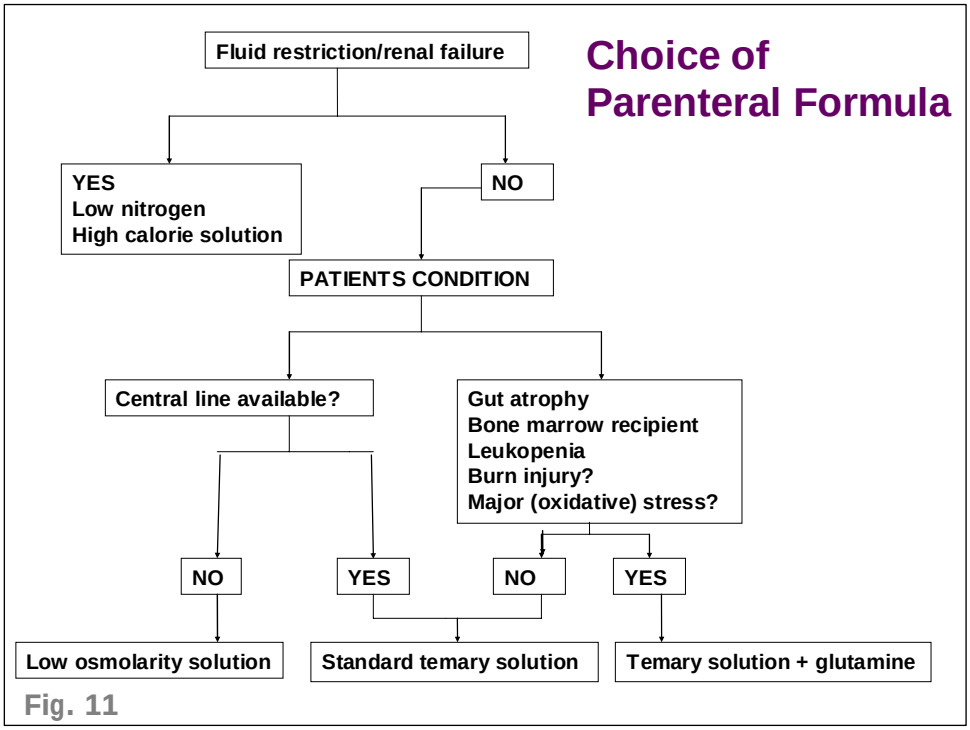

Fig. 11

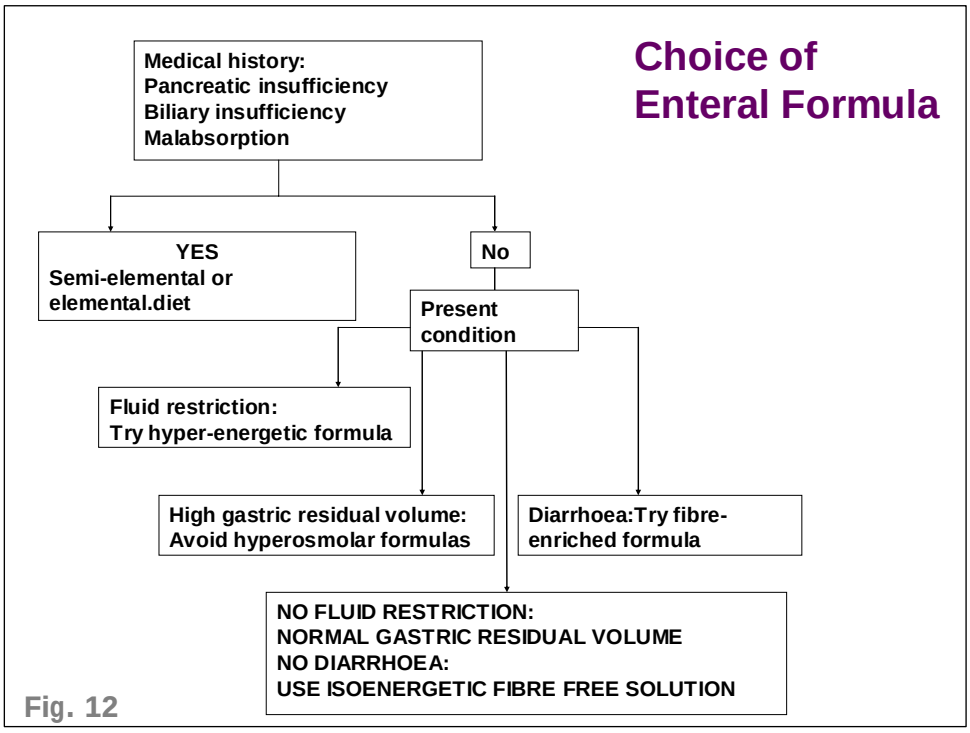

Fig. 12

References

1. Preiser JC, Chiolero R, Wernerman J. Nutritional papers in ICU patients: what lies between the lines? Intensive Care Med. 2003; 29:156-66.
2. Heyland DK, Schroter-Noppe D, Drover JW, Jain M, Keefe L, Dhaliwal R, Day A. Nutrition support in the critical care setting: current practice in canadian ICUs--opportunities for improvement? JPEN J Parenter Enteral Nutr. 2003; 27:74-83.
3. Preiser JC, Berre J, Carpentier Y, Jolliet P, Pichard C, Van Gossum A, Vincent JL. Management of nutrition in European intensive care units: results of a questionnaire. Working Group on Metabolism and Nutrition of the European Society of Intensive Care Medicine. Intensive Care Med. 1999;25:95-101
4. crutical care
5. www.nutritioncare.org.
6. Jolliet P, Pichard C, Biolo G, Chiolero R, Grimble G, Leverve X, Nitenberg G, Novak I, Planas M, Preiser JC, Roth E, Schols AM, Wernerman J. Enteral nutrition in intensive care patients: a practical approach. Clin Nutr. 199918:47-56.
7. Detsky AS, Smalley PS, Chang J Is this patient malnourished? JAMA. 1994 Jan 5; 271(1):54-8.
8. www.bapen.org.uk
9. Buzby GP, Knox LS, Crosby LO, Eisenberg JM, Haakenson CM, McNeal GE, Page CP, Peterson OL, Reinhardt GF, Williford WO. Study protocol: a randomized clinical trial of total parenteral nutrition in malnourished surgical patients. Am J Clin Nutr 1988; 47: 366-381.
10. www.mna-elderly.com
11. Ingenbleek Y, Carpentier YA. A prognostic inflammatory and nutritional index scoring critically ill patients *Int J Vitam Nutr Res* 1985; 55: 91-101.
12. Simpson F, Doig GS. Parenteral vs. enteral nutrition in the critically ill patient: a meta-analysis of trials using the intention to treat principle. Intensive Care Med. 2005; 31:12-23.
13. Peter JV, Moran JL, Phillips-Hughes J. A metaanalysis of treatment outcomes of early enteral versus early parenteral nutrition in hospitalized patients. Crit Care Med. 2005; 33:213-20.
14. Jeejeebhoy KN. Permissive underfeeding of the critically ill patient. Nutr Clin Pract. 2004; 19:477-480.
15. Crook MA, Hally V, Panteli JV. The importance of the refeeding syndrome.Nutrition. 2001; 17:632-7.
16. Wolfe RR. Herman Award Lecture, 1996: relation of metabolic studies to clinical nutrition--the example of burn injury. Am J Clin Nutr 1996; 64(5):800-8.