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TROPICAL AND GEOGRAPHICAL MEDICINE

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Chapter 112

Protein-Energy Malnutrition

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Protein-energy malnutrition (PEM) is the most important nutritional disease in the developing countries because of its high prevalence and its relationship with child mortality rates, impaired physical growth, and inadequate social and economic development. While associated deleterious effects on mental growth and maturation have been demonstrated in experimental animals [1,2] and they seem to occur in humans [3,4], it has not been possible to disassociate completely the nutritional factors from other environmental conditions, nor to ascertain the irreversibility of the nutritional mental damage.

PEM mainly affects infants and preschool-aged children. It occurs more frequently when infections impose additional demands or induce greater losses of dietary energy, total nitrogen, and essential amino acids, and when living conditions demand greater energy expenditure, as in heavy physical work. The inability to satisfy the needs for these nutrients leads to PEM of varying degrees of severity. It is estimated that in many developing countries between 20 and 66 percent of all children under 5 years of age had or presently have PEM [5]. Mild and moderate forms of adult PEM affect the physical and physiological performance of many millions of individuals.

PEM encompasses a wide spectrum of clinical syndromes conditioned by the relative intensity of protein or energy deficit, the severity and duration of the deficiencies, the age of the host, the etiology of the deficiency, and the association with other nutritional or infectious diseases. Its severity ranges from weight loss, without other clinical manifestations to kwashiorkor or marasmus. Its origin can be *primary*, as a result of inadequate food intake, or *secondary*, as a result of other diseases that lead to low food intake, inadequate nutrient utilization, and/or increased nutritional requirements.

This chapter deals only with *primary PEM of a relatively chronic onset*, where inadequate energy and/or protein intakes lead to the nutritional disease. The metabolic alterations and clinical characteristics of famine and of specific vitamin and mineral deficiencies are described in other sections of this book.

NUTRIENTS

Primary PEM results from insufficient food intake or from the ingestion of foods with proteins of poor nutritional quality. Dietary energy and protein deficiencies usually occur together, but sometimes one predominates and, if severe enough, may lead to the distinct clinical syndromes of *kwashiorkor* (predominant protein deficiency), *marasmus* (mainly energy deficiency), or *marasmic kwashiorkor* (chronic energy deficiency with chronic or acute protein deficit). It is difficult to recognize which deficit predominates in milder forms of the disease.

ABSORPTION AND UTILIZATION

Energy

The main dietary energy sources are carbohydrates and fats, but proteins can also provide energy. In order to be absorbed, carbohydrates must be hydrolyzed to monosaccharides by the action of amylases and disaccharidases; fats must be converted into fatty acids and monoglycerides, which requires bile salts and lipases; and proteins must be hydrolyzed into amino acids by several gastrointestinal proteases and peptidases. Assuming that carbohydrates, fats, and proteins are 99, 95, and 92 percent absorbed, respectively, and that each gram of urinary nitrogen represents 1.25 kcal of protein energy that was not utilized by the human body, Atwater proposed that the "metabolizable" energy contents of those food components were 4, 9, and 4 kcal/g, respectively. It is now known that the proteins of most predominantly vegetable diets are only 65 to 85 percent absorbed and total energy absorption from mixed animal-vegetable diets is usually 90 to 95 percent [6]. Nevertheless, the Atwater factors are still practical and their use results in a relatively small error.

Protein

The utilization of dietary proteins depends on their digestibility (i.e., absorption) and their amino acid composition. A protein that is deficient in one or more essential amino acids is not used adequately for the body's protein metabolism, although the nonutilized amino acids are potential energy sources when dietary carbohydrates and fats do not provide sufficient energy. The rational combination of poor-quality proteins to provide a

surplus amount of the essential amino acid that each one lacks will improve the protein quality of a diet. This quality can be expressed as a chemical or amino acid score, relative to a standard essential amino acid pattern. If the score is corrected by the protein digestibility, a good estimate of the protein's nutritional value is obtained [7] Protein deficiency can result from the intake of insufficient amounts of digestible protein (total nitrogen deficit), from the ingestion of poor-quality protein (essential amino acid deficit), or from a combination of both. A deficient dietary energy intake will also contribute to the development of protein deficiency by reducing the efficiency of protein utilization, altering amino acid metabolism, and increasing the nutritional requirements for protein [8].

ENERGY AND PROTEIN DENSITIES OF FOODS

Some vegetable foods have proteins and energy of good nutritional quality, but they are bulky and become more so as a result of the water absorbed during cooking. Consequently, their energy and protein densities (i.e., energy and protein per gram of cooked food, ready to be eaten) are low and they must be consumed in relatively large amounts to meet the body's requirements for these nutrients. This may lead to PEM, particularly in infants and preschool children whose appetites are satisfied and whose stomachs are filled with quantities of bulky foods that do not provide sufficient amounts of proteins or energy [9].

INTERACTIONS WITH OTHER NUTRIENTS

Poor energy and protein intakes are accompanied by insufficient intakes of other essential nutrients. In severe PEM there can be deficiencies of vitamins, such as A, E, folic acid, and B_{12}; trace minerals such as iron, zinc, selenium, and chromium; and electrolytes such as potassium and magnesium. Their clinical and metabolic significance depend on the severity of the specific micronutrient deficit relative to that of PEM. In kwashiorkor and marasmus, manifestations of energy and protein insufficiency usually predominate and some of the other nutrient deficiencies only become clinically evident during the course of protein-energy repletion. This can be either because the derangement caused by severe PEM overshadows other symptoms or because the functional requirements for some micronutrients diminish in severely malnourished patients and increase only during the period of nutritional rehabilitation. The latter situation is exemplified by iron: patients with kwashiorkor and marasmus usually have low hemoglobin concentration, even when the levels of serum iron and plasma ferritin are normal; the administration of additional iron does not produce a reticulocyte response nor an increase in hemoglobin synthesis until dietary therapy with energy and protein begins replenishing the depleted body mass. The reduced synthesis of hemoglobin is not a "functional" anemia, but a physiological adaptation to low protein intakes in the presence of decreased demand for oxygen transport as a consequence of the reduced lean body mass and low physical activity characteristic of severe PEM [10].

These "hidden" nutrient deficits are important during treatment of PEM. For example, functional anemia and hypoxia may develop if hematinics are not provided as tissue synthesis and oxygen demands increase; failure to replete nearly exhausted vitamin A stores can precipitate severe ocular manifestations of hypovitaminosis A; muscular tone and other cell functions will recover very slowly unless enough potassium is provided to overcome the intracellular depletion of this electrolyte; covert zinc deficiency may retard catch-up growth.

PATIENT

PATHOPHYSIOLOGY AND ADAPTIVE RESPONSES

PEM develops gradually over many days or months. This allows a series of metabolic and behavioral adaptations which result in decreased nutrient demands and in a nutritional equilibrium compatible with a lower level of cellular nutrient availability. Patients whose PEM develops slowly—as is usually the case in marasmus—are better-adapted to their current nutritional status and maintain a less fragile metabolic equilibrium than those with more acute PEM, as in kwashiorkor of rapid onset.

Energy mobilization and expenditure

A decrease in energy intake is quickly followed by a decrease in energy expenditure, accounting for shorter periods of play and physical activity in children [11,12] and for longer rest periods and less physical work in adults [13]. When the decrease in energy expenditure cannot compensate for the insufficient intake, body fat is mobilized with a decrease in adiposity and weight loss. Lean body mass diminishes at a slower rate, mainly as consequence of muscle protein catabolism with increased efflux of amino acids, primarily alanine. As the cumulative energy deficit becomes more severe, subcutaneous fat is markedly reduced, and protein catabolism leads to muscular wasting. Visceral protein is preserved longer, especially in the marasmic patient. In marasmus, these alterations in body composition lead to increased basal oxygen consumption (i.e., basal metabolic rate) per unit body weight. In kwashiorkor, the severe dietary protein deficit leads to an earlier visceral depletion of amino acids that affects visceral cell function and reduces oxygen consumption; therefore, basal energy expenditure decreases per unit of lean or total body mass. Blood glucose concentration remains normal, mainly at the expense of fats

and gluconeogenic amino acids, and it falls in very severe PEM or when complicated by serious infections or fasting.

Protein metabolism

The most striking changes are a marked recycling of amino acids and a reduction in urea synthesis and excretion. The poor availability of dietary amino acids decreases protein synthesis in viscera and muscles. This is followed by increased muscle protein catabolism, modifies composition of the free amino acid pool, and increased visceral amino acid availability. In the steady state, the amount of free amino acids entering the body pool is equal to the amount leaving it. The latter is represented by the amino acids synthesized into body protein and the amount of amino acid nitrogen that is excreted. On a normal protein intake, 25 percent of the amino acids leaving the total body pool are excreted as nitrogenous compounds and 75 percent are recycled or reutilized for protein synthesis. This latter fraction may rise to 90 to 95 percent when protein intake is reduced [*14*]. Therefore, the adaptive change is not so much a reduction of total nitrogen or amino acid turnover but an increase in the proportion turned over that is used for synthesis and a corresponding reduction in the proportion of nitrogen that is excreted.

The half-life of some proteins increases. The rate of albumin synthesis decreases, but after a time lag of a few days the rate of breakdown also falls [*15*]. In addition to its increased half-life, a shift of albumin from the extravascular to the intravascular pool assists in maintaining adequate levels of circulating albumin in the face of reduced synthesis, until protein depletion becomes so severe that it disrupts these adaptive mechanisms. The ensuing reduction in intravascular oncotic pressure and the outflow of water into the extravascular space contribute to the development of the edema of kwashiorkor.

These adaptations lead to the sparing of body protein and the preservation of essential protein-dependent functions. The gradual and inevitable loss of body protein as a result of long-term dietary protein deficit is primarily from skeletal muscle. Some visceral protein is lost in the early development of PEM but then becomes stable until the nonessential tissue proteins are depleted; the loss of visceral protein then increases, and death may be imminent unless nutritional therapy is successfully instituted.

Endocrine changes

Hormones play an important role in the adaptive metabolic processes. Endocrine changes may not be wholly explained by

Table 112-1. Some metabolic effects and secretion or circulating levels of selected hormones usually seen in severe protein-energy malnutrition

Hormone	Stimulus	Metabolic effects of hormone	Hormonal activity	
			In energy deficit	In protein deficit
Insulin	↑ Glucose	↑ Protein synthesis (muscle)	Decreased	Decreased
	↑ Amino acids	↑ Lipogenesis		
		↑ Growth		
Somatomedins	?	↑ Protein synthesis (muscle, cartilage)	?	Decreased
		↑ Lipogenesis		
		↑ Growth		
		↑ Collagen synthesis		
Growth hormone	↓ Glucose	↑ Protein synthesis (muscle, visceral)	Normal or moderately increased	Increased
	↑ Amino acids	↑ Lipolysis		
		↑ Growth		
Glucorticoids	↓ Glucose	↑ Protein catabolism (muscle)	Increased	Normal or moderately increased
	↓ Amino acids	↑ Protein turnover (visceral)		
		↑ Lipolysis		
		↑ Gluconeogenesis		
Thyroid hormones	?	↑ Protein turnover	Normal or decreased	Variable, usually decreased
		↑ Lipolysis		
		↑ Glucose oxidation		

the circulating levels of hormones, since cellular responses to hormonal stimulation may also be altered in PEM. Table 112-1 summarizes the main changes in hormonal activity seen in patients with severe energy or protein deficiencies. The functional capacities of the hypothalamic-pituitary axis and the adrenal medulla are preserved. Consequently, patients can still show endocrine and metabolic responses to stress conditions.

Some endocrine adaptive functions in severe PEM are related to energy metabolism (Fig. 112-1): (1) The decreased food intake tends to reduce plasma concentrations of glucose and free amino acids which, in turn, *reduce insulin* secretion and *increase epinephrine* release. The low plasma amino acid levels, seen mainly in kwashiorkor, also *stimulate the secretion of human growth hormone*. (2) The *low plasma somatomedin* activity, also seen mainly in kwashiorkor, probably contributes to the high circulating levels of growth hormone, due to the absence of the feedback inhibition postulated for somatomedins. (3) The stress induced by the low food intake and further amplified by fever, water and electrolyte losses, and other manifestations of the infections that frequently accompany PEM, also *stimulates epinephrine release* and *corticosteroid secretion*, more so in marasmus than in kwashiorkor, probably because of the greater severity in energy deficit that characterizes marasmus. (4) The plasma concentrations of T_3 *and* T_4 *decrease*, by mechanisms that are not yet defined; the iodination of tyrosine may be involved, as the reduction in T_3 (3,5,3′-triiodothyronine) is accompanied by an increase in the circulating levels of the metabolically inactive reverse-T_3 (3,5,5′-triiodothyronine). All these changes contribute to the maintenance of energy homeostasis through increased glycolysis and lipolysis; increased amino acid mobilization; decreased storage of glycogen, fats, and proteins; and decreased energy metabolism. They also participate in the preservation of visceral protein through increased breakdown of muscle protein and increased availability and turnover of amino acids in viscera, particularly liver. Some investigators [*16*] have postulated that the evolution of PEM into either kwashiorkor or marasmus may be partly related to differences in adrenocortical response, whereby the better response will preserve visceral proteins more efficiently and lead to the better-adapted syndrome of marasmus.

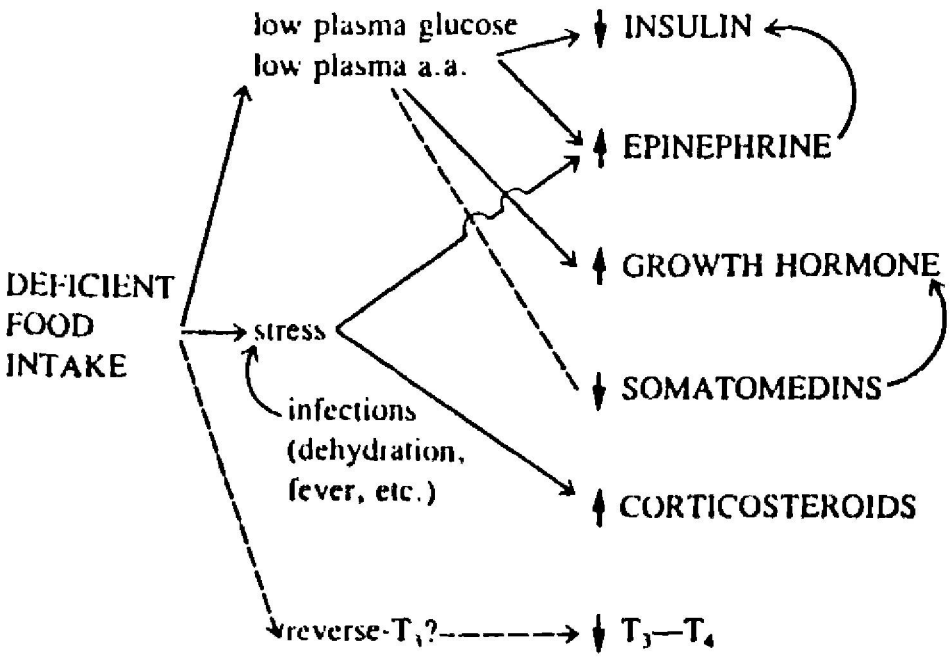

Figure 112-1. Endocrine adaptive functions in severe PEM related to energy metabolism.

Disruption of adaptation

Patients with severe PEM adapt to a new, but fragile, state of metabolic equilibrium. The adaptive mechanisms can be upset by large increases in the intake of energy relative to proteins, by infections, and by a sudden, large increase in energy and/or protein intake. For example, the abrupt administration of high-carbohydrate diets with poor protein intake will induce insulin secretion and reduce the release of epinephrine, growth hormone, and cortisol. Consequently, fat oxidation and gluconeogenesis decrease and the availability of muscle amino acids for liver protein synthesis diminishes. These changes may lead to the development or exacerbation of kwashiorkor.

Patients with kwashiorkor suddenly fed large amounts of proteins or given large transfusions of plasma or blood may experience a rapid increase in intravascular protein concentration and entry of extracellular fluid into the vascular compartment leading to cardiovascular insufficiency and pulmonary edema. In fact, a too early introduction of high-energy or high-protein diets to a severely malnourished patient may be fatal [*17*].

ASSESSMENT OF NUTRIENT STATUS

The assessment and classification of moderate forms of PEM is based on anthropometric measurements, since biochemical indexes usually do not show changes unless the disease is well advanced. More accurate measurements, such as assessment of body composition, are not practical or feasible in most of the settings where PEM occurs, and the so-called functional indicators (Chap. 22) are not as yet well defined or standardized. Severe PEM can be classified qualitatively to distinguish kwashiorkor, marasmus, and intermediate forms, based on clinical and biochemical criteria.

Anthropometric measurements

The anthropometric assessment of nutritional status employs a standard reference of comparison but not necessarily an ideal or a target. Any set of reliable anthropometric data can be used as the standard, but the interpretation of their use (i.e., the line

that separates "normal" from "deficient" and further subdivisions into "mild," "moderate," and "severe" forms) is a matter of judgment. In order to allow international comparisons, it is sensible to use the same standard of reference for various populations. The value judgment comes into play when deciding whether the expected normal value for a given population should be 100 percent, 90 percent, or other proportion of the standard. Setting different cutoff points relative to a single standard is more practical than constructing local standards which, in a country with heterogeneous population groups, may pose the same problem as a "foreign," commonly used reference. The World Health Organization presently recommends the data from the U.S. National Center for Health Statistics (NCHS) [*18*] as reference.

The choice of anthropometric indexes will depend on the simplicity, accuracy, reproducibility, and sensitivity of the measurements, and on the availability of measuring instruments. The most widely used index for children, although not the best, is *weight for age*. This was the basis for classifying PEM into three degrees [*19*]: first degree = 90 to 75 percent of standard, second degree = 74 to 60 percent, third degree = less than 60 percent. The use of this index, however, does not differentiate between a truly underweight child and one who is short in stature but well-proportioned in weight. Furthermore, the information about chronological age is not always reliable.

The measurement of height or length, in addition to weight, is important. It allows the use of two indexes: *weight for height*, as an index of *current* nutritional status, and *height for age*, as an index of *past* nutritional history which, when deficient, may represent a short period of growth failure at an early age or a longer period at a later age. Waterlow [*20*] suggested the term "wasting" for a deficit in weight for height, and "stunting" for a deficit in height for age. Children may fall into four broad categories that are qualitatively different: (1) normal, (2) wasted but not stunted (suffering from acute PEM), (3) wasted and stunted (suffering from acute and chronic PEM), and (4) stunted but not wasted (past PEM with present adequate nutrition, or "nutritional dwarfs"). The severity of wasting and stunting can be graded using, respectively, weight as percentage of the expected median weight of a standard child of the same height, and height as percentage of the median standard height for age. The grading shown in Table 112-2 is suggested for most countries. It may be convenient to use different points of demarcation for some populations (e.g., normal height for age in groups that are genetically short could be less than 95 percent of the standard).

Other anthropometric indexes have been used, such as the developmental quotient for weight or height (weight-age or height-age divided by the chronological age) [*21*], midarm circumference in absolute terms [*22*] or relative to height (QUAC-stick) [*23*], or weight, ratio of arm circumference to head circumference [*24*]. It seems, however, that an international classification of PEM should be based primarily on weight, height, and, when available, age [*20*].

Table 112-2. Grading of severity of current ("wasting") and past or chronic ("stunting") malnutrition

	Normal	Mild	Moderate	Severe
Weight for height (deficit = wasting)	90–110*	80–89	70–79	<70
Height for age (deficit = stunting)	95–105	90–94	85–89	<85

*Percentage of the median NCHS standard (Ref. 23).
Source: From [*24*].

Body composition

Measurements of adiposity and lean body mass provide a better assessment of mild and moderate PEM than anthropometric measurements in adults. Since energy deficiency is usually more common than protein deficiency, the most striking change is a reduction of adiposity below the average 12 and 20 percent expected in normal, well-nourished men and women, respectively.

Fat stores are reduced in severe PEM and virtually depleted in marasmus; a notable exception are the classic cases of kwashiorkor where patients have had an adequate energy intake with a very poor protein intake. Body protein decreases at a slow rate, most of it from muscle, and the greater loss of adipose tissue results in a relative increase of total body water (i.e., per unit of body mass), mainly as intracellular water. In severe protein deficiency (kwashiorkor) there is also an increase in extracellular water. The intracellular concentrations of potassium and magnesium decrease and that of sodium increases, although the serum concentrations of electrolytes do not necessarily reflect these alterations [*25*].

Functional alterations

Physical activity and energy expenditure decrease with insufficient dietary energy intakes [*11–13*], but the methods to assess such changes are complex. Other functional assessments related to immunocompetence, intellectual and behavioral responses, and gastrointestinal functions have been or are currently being investigated. Their application to assess nutritional status is complicated by the environmental conditions and high morbidity rates that usually prevail where PEM develops. Nevertheless, this is a promising line of research that may also indicate important physiological or social implications of moderate PEM that are frequently overlooked.

CLINICAL MANIFESTATIONS

Mild and moderate PEM

The main clinical feature of mild and moderate PEM in children is a retardation in physical growth. Present malnutrition results in wasting (low weight for height) and past malnutrition in stunting (low height for age). The combination of wasting and stunting suggests chronic malnutrition with present inadequate nutritional status. In adults, mild to moderate or chronic PEM results in leanness with a more or less marked reduction in subcutaneous tissue.

Nonspecific manifestations include reduced physical activity, frequent episodes of diarrhea and apathy, lack of liveliness, and short attention spans.

Marasmus

Severe muscular wasting and absence of subcutaneous fat give the patient a "skin-and-bones" appearance (Fig. 112-2). Marasmic persons frequently have 60 percent or less of the weight expected for their height, with marked retardation in longitudinal growth. The hair is sparse, thin, and dry; the skin is usually dry, thin, with little elasticity and wrinkles; and lymph nodes are easily palpable. The patient is weak and frequently cannot stand without help. Heart rate, blood pressure, and body temperature may be low. Hypothermia of 35°C or less can occur, especially after fasting a period, and is often accompanied by hypoglycemia.

The marasmic child is apathetic but usually aware and with a look of anxiety on his or her face. These features and the

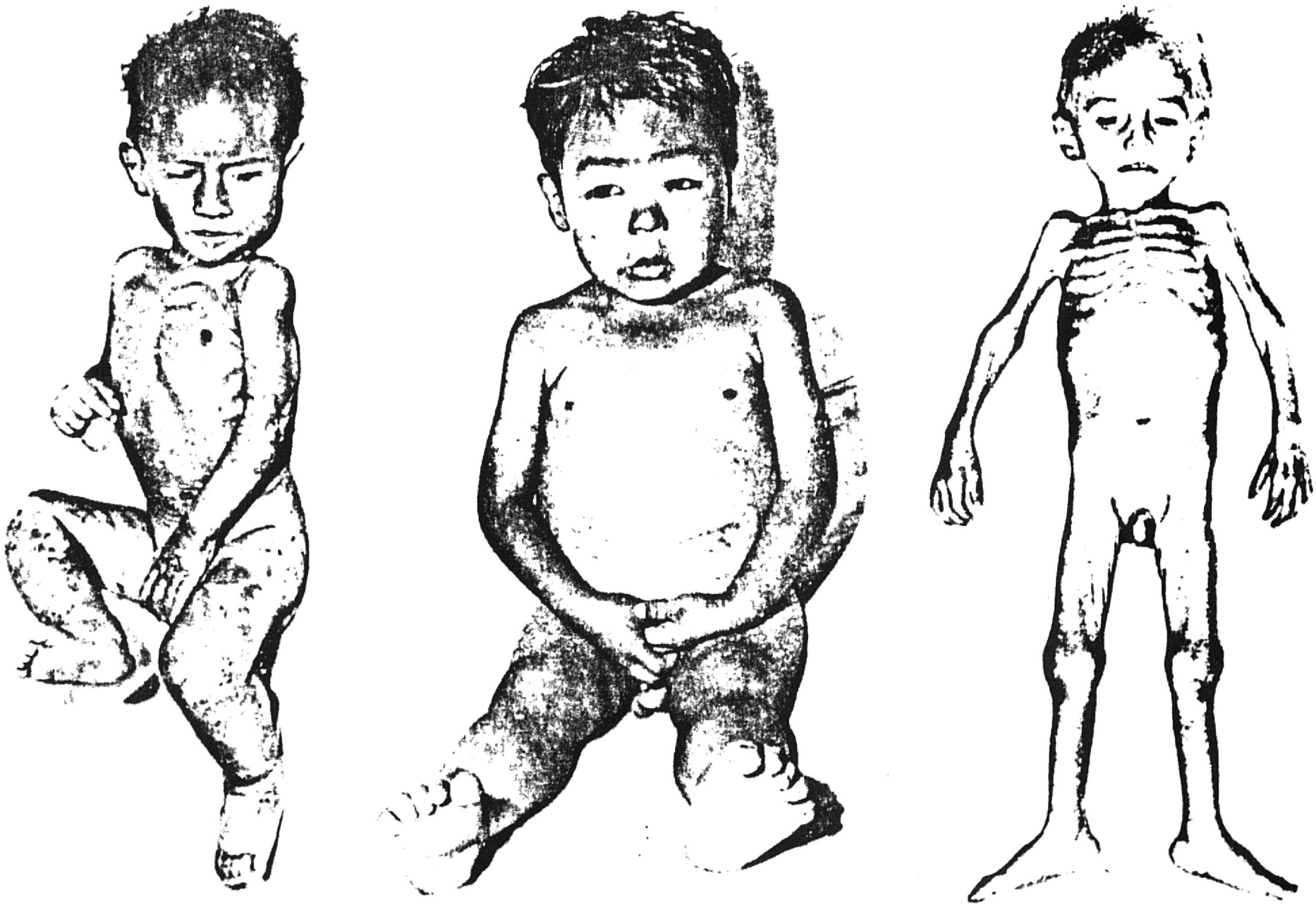

Figure 112-2. "Skin-and-bones" appearance of marasmic patient.

sunken cheeks caused by disappearance of the Bichat fat-pads, which are among the last subcutaneous adipose depots to disappear, give the marasmic child's face the appearance of a monkey's or an old person's. Some patients are anorexic while others are ravenously hungry, but they seldom tolerate large amounts of food and vomit easily.

Common complicating features are acute gastroenteritis, dehydration, respiratory infections, eye lesions due to hypovitaminosis A, and skin infections. Systemic infections can be present without an appropriate febrile response, tachycardia, or leukocytosis.

Kwashiorkor

The predominant feature is soft, pitting, painless edema, usually in the feet and legs, but extending to perineum, upper extremities, and face in severe cases (Fig. 112-2). Subcutaneous fat is preserved, although there may be some muscle wasting. Weight deficit, after accounting for the edema, is not as severe as in marasmus. Height is variable and may be normal or retarded, depending on the chronicity of the current episode and on past nutritional history. The hair is dry, brittle, without its normal sheen, and can be pulled out easily and without pain. Curly hair becomes straight, and there usually are changes in pigmentation, becoming dull brown, reddish, or even yellowish-white. Alternating periods of poor and relatively good protein intake can produce alternating bands of depigmented and normal hair, which have been termed the "flag sign." Skin lesions, often confused with pellagra, are very characteristic of kwashiorkor. They occur in many but not all patients more frequently in the areas of edema, continuous pressure (e.g., buttocks and back), or frequent irritation (e.g., perineum and thighs). In those areas the skin may be erythematous and it glistens in the edematous regions with zones of dryness, hyperkeratosis, and hyperpigmentation, which tend to become confluent. The epidermis peels off in large scales, exposing underlying tissues that are easily infected. The patients may be pale, with cold and cyanotic extremities. Hepatomegaly with a soft, round edge, caused by severe fatty infiltration is usually present. The abdomen is frequently protruding because of distended stomach and intestinal loops. Peristalsis is irregular. Muscle tone and strength are greatly reduced and tachycardia is common. Both hypothermia and hypoglycemia can occur after short periods of fasting.

Patients are simultaneously apathetic and irritable and have an expression of misery and sadness. Anorexia, sometimes necessitating nasogastric tube feeding, postprandial vomiting, and diarrhea are common. These improve without specific gastrointestinal treatment as nutritional recovery progresses.

Diarrhea and respiratory infections are more frequent and severe in kwashiorkor compared to marasmus. Severe, even fatal infections may occur as in marasmus, but without fever, tachycardia, respiratory distress, or leukocytosis.

Marasmic kwashiorkor

This form of edematous PEM combines clinical characteristics of kwashiorkor and marasmus. The main features are the edema of kwashiorkor, with or without its skin lesions, and the muscle wasting and decreased subcutaneous fat of marasmus (Fig. 112-2). When edema disappears during early treatment, the patient's symptoms resemble a case of marasmus. Biochemical features of both marasmus and kwashiorkor are seen, but the alterations of severe protein deficiency usually predominate.

DIAGNOSIS

Mild and moderate PEM

The diagnosis is based on dietary history and anthropometric measurements. Biochemical indicators are of little help, although the patients may have low urinary excretions of urea nitrogen, creatinine, hydroxyproline, and 3-methylhistidine, and a small decrease in serum concentrations of branched-chain essential amino acids, albumin, and transferrin.

Severe PEM

The diagnosis is principally based on dietary history and clinical features. The most common biochemical findings are that serum concentrations of total proteins and albumin are markedly reduced in edematous PEM, and normal or moderately low in marasmus; hemoglobin and hematocrit are usually low, more so in kwashiorkor than marasmus; the ratio of nonessential to essential amino acids in plasma is elevated in kwashiorkor and usually normal in marasmus; serum levels of free fatty acids are elevated, particularly in kwashiorkor; blood glucose level is normal or low, especially after fasting 10 to 12 h; urinary excretions of creatinine, hydroxyproline, 3-methylhistidine and urea nitrogen are low; children usually have low urinary creatinine excretions in relation to their height, leading to a low creatinine-height index [26], whereas marasmic children may have a normal or somewhat low index.

Plasma levels of other nutrients vary and tend to be moderately low. They do not necessarily reflect the body stores. For example, serum iron and retinol may be normal with almost depleted body stores, or in kwashiorkor they may be relatively low with adequate stores because of alterations in the transport proteins, transferrin, and retinol-binding protein.

Many other biochemical changes have been described in severe PEM. They have little practical diagnostic importance

but give an insight into the pathophysiological changes (Table 112-3).

PROGNOSIS AND RISK OF MORTALITY

Treatment usually takes longer in marasmus than kwashiorkor. Mortality rates in severe PEM can be as high as 40 percent. Immediate causes of death are usually infections. Table 112-4 lists the characteristics that generally indicate a poor prognosis.

Anthropometric characteristics are also associated with mortality rates, as in the classification of severe PEM into first, second, or third degrees, based on weight for age [*19*]. A higher mortality rate is associated with the more intense anthropometric deficits but not with mild or moderate deficiencies [*27*].

Table 112-4. Manifestations in patients with protein-energy malnutrition that generally indicate a poor prognosis

1. Age less than 6 months
2. Deficit in weight for height of greater than 30%, or in weight for age of greater than 40%
3. Extensive exfoliative or exudative cutaneous lesions or deep decubitous ulceration
4. Dehydration and electrolyte imbalances, especially hypokalemia and severe acidosis
5. Clinical jaundice or elevated serum bilirubin concentrations, with or without elevations in the transaminases
6. Hypoglycemia or hypothermia
7. Total serum protein concentrations less than 3 g/dL
8. Severe anemia with hypoxia
9. Petechiae or hemorrhagic tendencies (purpura is usually a sign of septicemia or a viral infection)
10. Intercurrent infections, particularly measles and bronchopneumonia
11. Persistent tachycardia and/or respiratory difficulty
12. Coma, stupor, or other alterations in mental status and consciousness

Source: Modified after B Torún, FE Viteri, Rev Col Med (Guatemala) 27:43–62, 1976.

TREATMENT

Severe PEM

Whenever possible, patients with noncomplicated PEM should be treated on an outpatient basis. Hospitalization increases the risk of cross-infections and the unfamiliar setting may increase apathy and anorexia in children, making feeding more difficult. When hospitalization is necessary, treatment strategy can be divided into three stages: (1) resolving life-threatening conditions, (2) restoring nutritional status without disrupting homeostasis, and (3) ensuring nutritional rehabilitation.

Table 112-3. Selected biochemical changes observed in severe protein-energy malnutrition

	Marasmus	Edematous PEM
Body composition		
Total body water	High	High
Extracellular water	High	Higher
Total body potassium	Low	Lower
Total body protein	Low	Low
Serum or plasma		
Transport proteins*	Normal or low	Low
Branched-chain amino acids	Normal or low	Low
Tyrosine/phenylalanine ratio	Normal or low	Low
Enzymes (in general)†	Normal	Low
Transaminases	Normal or high	High
Liver		
Fatty infiltration	Absent	Severe
Glycogen	Normal or low	Normal or low
Urea cycle and other enzymes‡	Low	Lower
Amino acid–synthesizing enzymes	High	Not as high

*For example, transferrin, ceruloplasmin, retinol-, cortisol-, and thyroxine-binding proteins, α- and β-lipoproteins.
†For example, amylase, pseudocholinesterase, alkaline phosphatase.
‡For example, xanthine oxidase, glycolic acid oxidase, cholinesterase.

RESOLVING LIFE-THREATENING CONDITIONS

Most in-hospital deaths occur in the first week of treatment. Nutritional rehabilitation can be delayed until emergencies are solved. The most frequent complications that require immediate treatment are

1. Fluid and Electrolyte Disturbances The assessment of dehydration is not easy in severe PEM, as classic signs of dehydration, such as sunken eyeballs and decreased skin turgor, are frequently found in well-hydrated patients, while hypovolemia may coexist with subcutaneous edema. Useful signs are low urinary output, weak and rapid pulse, and low blood pressure and a declining state of consciousness, which indicate impending circulatory collapse.

Whenever possible, oral or nasogastric rehydration should be used. Intravenous fluids must be used in severe dehydration with hypovolemia, impending shock, frequent vomiting, and persistent abdominal distension. The therapeutic approach differs from that in well-nourished patients because of hydroelectrolytic peculiarities of severe PEM, namely: (1) hypoosmolarity with moderate hyponaturemia, frequently with intracellular sodium excess; (2) intracellular potassium depletion, usually without hypokalemia; (3) mild-to-moderate met-

abolic acidosis, which decreases or disappears when the patient receives dietary or parenteral energy, and electrolyte balance is reestablished; (4) high tolerance to hypocalcemia, partly because of the acidosis, which produces a relative increment in ionized Ca^{2+}, and partly because of hypoproteinemia, which makes less protein available to bind Ca^{2+}; (5) decreased body magnesium, with or without hypomagnesemia.

The volume of fluids will depend on diuresis and the clinical signs of dehydration. Fluid repletion should allow a diuresis of at least 200 mL in 24 h in children and 500 mL in adults, or a micturition every 2 to 3 h. As a guideline, 10 mL/(kg·h) by mouth or nasogastric tube every 1 to 2 h can be given initially to be modified according to patient response. The following treatment plan is based on extensive experience at the Institute of Nutrition of Central America and Panama (INCAP). Patients with edema who are urinating should receive about 6 meq K, 2 to 3 meq Na, 2 to 3 meq Ca, and 20 to 30 kcal/day per kilogram of body weight. This can be accomplished by dissolving in 1 L of water, 3 g KCl, 1 g table salt (NaCl), 2 g $CaCl{\cdot}6H_2O$ (or 4 g calcium gluconate), and 50 g glucose or cane sugar. Potassium should be withheld when there is no diuresis. Additional fluids must be given to compensate for the losses of diarrhea and vomiting, providing about 35 meq Na and 30 meq K per kilogram of excreta (i.e., 2 g table salt and 2 g KCl per liter). Dietary formula with calcium should be started as early as possible, if necessary alternating with the electrolyte solution. Total K intake should be raised to 8 to 10 meq/(kg·day) while for Mg 0.5 to 1 meq/(kg·day) should be given.

When intravenous infusions are necessary, osmolarity must be kept low (200 to 280 mosmol/L), K and Na should not exceed 6 and 3 meq/(kg·day), respectively, and glucose must provide 15 to 30 kcal/(kg·day). During the first hour, 10 to 30 mL/kg is infused, depending on the patient's condition. Subsequent volumes are calculated at 2- to 4-h intervals. Additional losses through diarrhea and vomiting must be compensated with about 3 meq Na, 3 meq K, 6 meq Cl, and 15 kcal per 100 g (i.e., 20 mL isotonic saline, 2 mL of 10% KCl, and 78 mL of 5% dextrose per 100 g excreta). An increase in pulse and respiratory rate with weight gain after accounting for weight of excreta, pulmonary rales, and appearance or exacerbation of edema indicates overhydration. An increase in pulse and respiratory rate with weight loss, low urine output, and continuing losses from diarrhea and vomiting suggests insufficient fluid therapy.

Patients with severe hypoproteinemia (less than 3 g/dL), anuria, and signs of hypovolemia or impending circulatory collapse should be given 10 mL plasma per kilogram in 1 to 2 h, followed by 20 mL/(kg·h) of a mixture of two parts of 5% dextrose and one part of isotonic saline, for 1 or 2 h. This will increase plasma protein concentration by about 0.5 to 1 g/dL and help prevent the rapid exit of water from the intravascular compartment. If diuresis does not improve, the dose of plasma can be repeated 2 h later. Further treatment is similar to that of well-nourished patients.

Some clinicians advocate the routine use of lactate- or bicarbonate-containing solutions. However, the mild metabolic acidosis of malnutrition usually disappears with energy intake. Therefore, treatment for acidosis should be withheld unless blood pH is below 7.25, urinary pH is below 5, or there are clinical signs of severe acidosis.

When there is hypomagnesemia or clinical signs similar to hypocalcemia that do not respond to calcium infusion, magnesium should be given intramuscularly as a 50% solution of magnesium sulfate in doses of 0.5, 1, and 1.5 mL, respectively, for patients who weigh less than 7, between 7 and 10, and more than 10 kg. The dose can be repeated as required every 12 h.

2. Infections Malnourished patients are particularly prone to infections. While these are often severe and life-threatening, paradoxically, clinical manifestations may be mild and the classic signs of fever, tachycardia, and leukocytosis absent. Antigen-antibody reactions are often impaired and skin tests, such as tuberculin, often give falsely negative results.

Antibiotics should not be used prophylactically, but when an infection is suspected appropriate antibiotic therapy must be started immediately, even before obtaining the results of microbiological cultures. The choice of drug will vary with the suspected etiological agent, the severity of the disease, and the pattern of the drug resistance in that area. Clinicians should be aware that gastrointestinal, hepatic, and renal alterations that might accompany severe PEM could potentiate a drug's toxic effects. Where septicemia is suspected, a broad-spectrum antibiotic or a combination, such as ampicillin and gentamicin, is usually given intravenously. Other supportive treatment may also be necessary, as for respiratory distress, hypothermia, and hypoglycemia.

Treatment for intestinal parasites is rarely urgent and can be deferred until nutritional rehabilitation is underway. This will decrease the risks of potential toxicity, including the possibility of absorbing drugs normally not absorbed by a healthy intestine.

3. Hemodynamic Alterations Cardiac failure may develop during or after administration of intravenous fluids, or shortly after the introduction of high-protein and high-energy feedings, leading to pulmonary edema and secondary pulmonary infection. These alterations may be the result of impaired cardiac function, sudden expansion of the intravascular fluid volume, severe anemia or impaired membrane function. Diuretics such as furosemide (10 mg IV or IM, repeated as necessary) should be given, as well as other supportive measures. Many clinicians advocate the use of digoxin (0.03 mg/kg IV, every 6 to 8 h). The use of diuretics merely to accelerate the disappearance of edema in kwashiorkor is contraindicated.

4. Severe Anemia Blood transfusions should be given only in cases of severe anemia with less than 4 g hemoglobin per deciliter, or with signs of hypoxia or impending cardiac failure. Whole blood (10 mL/kg) can be used in marasmic patients, but it is better to use packed red blood cells (6 mL/kg) in edematous PEM. The transfusion should be given slowly, over 2 to 3 h, and repeated if necessary after 12 to 24 h. The routine use of blood transfusions endangers the patient, and hemoglobin levels will improve with proper dietary treatment supplemented with hematinics.

5. Hypothermia and Hypoglycemia Body temperature below 35.5°C and plasma glucose concentration below 60 mg/dL can be due to either impaired thermoregulatory mechanisms, reduced fuel substrate availability, or severe infection. Asymptomatic hypoglycemia can be treated (and prevented) by the frequent feeding of small volumes of glucose-containing diets and solutions. Severe symptomatic hypoglycemia must be treated intravenously with 10 to 20 mL of 50% glucose solution followed by oral administration of 25 to 50 mL of 5% glucose solution at 2-h intervals for 24 to 48 h.

Body temperature usually rises in the hypothermic patient with frequent feedings of glucose-containing diets or solutions. Caution and close monitoring of body temperature must be used with external heat sources and devices to reduce the loss of body heat, as these patients may rapidly become hyperthermic. It is best to keep the seminude patients in an ambient temperature of 30 to 33°C.

6. Severe Vitamin A Deficiency Severe PEM is often associated with vitamin A deficiency. A large dose of vitamin A should be given on admission, since ocular lesions can develop as adequate protein and energy feeding begins and the metabolic demands for retinol increase. Water-miscible vitamin A should be given orally or IM on the first day, at a dose of 50,000 to 100,000 IU for infants and preschool children, or 100,000 to 200,000 IU for older children and adults, followed by 5000 IU orally each day for the duration of treatment. The initial dose should be repeated two more days in symptomatic cases. Corneal ulcerations should be treated with ophthalmic drops of 1% atropine solution and antibiotic ointments or drops until the ulceration heals.

HOMEOSTATIC RESTORATION OF NUTRITIONAL STATUS

The next objective of therapy is to replace tissue deficits as rapidly and as safely as possible. Based on the premise that the patient is adapted to the malnourished state, nutritional treatment must begin slowly. Various regimens provide a diet that meets daily maintenance requirements for a few days, followed by a gradual increase in nutrient delivery. Table 112-5 shows a therapeutic schedule for children, based on INCAP's experience. The only difference between kwashiorkor and marasmus is that the latter often requires larger amounts of dietary energy, which must be raised at 5-day intervals, depending on the patient's weight gain. The intervals for the dietary increments in Table 112-5 can be lengthened to 3 to 5 days in very severely malnourished children, especially those with plasma protein less than 3 g/dL or with serious metabolic disturbances.

It is best to begin with a liquid formula fed orally or by nasogastric tube, divided equally into 5 to 12 feedings per day, depending on the patient's age and general condition. This frequent feeding of small volumes avoids vomiting and prevents the development of hypoglycemia and hypothermia. Intravenous feeding is rarely justified in primary PEM.

The attitude of the person who feeds the patient and the appearance, color, and flavor of the foods influence appetite. For older children with good appetite, the liquid formula can be partly substituted with solid foods that have a high density of good quality, easily digestible nutrients.

The diet must be supplemented to provide 8 to 10 meq of potassium, 3 to 5 meq of sodium, 5 to 8 meq of calcium, and 1 to 2 meq of magnesium per kilogram of body weight per day. This can be accomplished by adding 0.3 g KCl and 0.1 g NaCl per 100 mL to milk formulas, or by adding appropriate amounts of the mineral mixture shown in Table 112-6 to most other diets. Additional supplements should include daily doses of 60 to 120 mg elemental iron, 10 mg elemental zinc, 0.3 mg folic acid, 5000 IU vitamin A, and other vitamins and trace elements in the doses provided by most commercial preparations.

The protein source must be of high biological value and easily digested. Cow's milk is frequently available but some

Table 112-5. Example of a dietary therapeutic regimen for children based on dry skim milk, sugar, and vegetable oil*

Days from beginning of treatment	Protein, g	Energy, kcal	Milk, g	Sugar, g	Oil, mL	Water, mL
1	0.8–1	80–100	3	17	2	100
3	1.5–2.5	110–120	6	20	2	130
5	2.5–3.5	140–150	9	20	4	150
7	3.5–4.5	150–160	12	20	4	160
12 (marasmust†)	3.5–4.5	175†	12	20	6†	160
17	3.5–4.5	195	12	20	8	160
22	3.5–4.5	215	12	20	11	160
etc.	3.5–4.5	†	12	20	†	160

*All amounts per kilogram of body weight per day. The liquid formula must be supplemented with adequate levels of vitamins, minerals, and electrolytes.

†Marasmic patients may require more dietary energy. Two to three milliliters of vegetable oil per kilogram per day should be added at 5-day intervals until the rate of weight gain becomes adequate.

Source: From FE Viteri, B Torún, in RS Goodhart, ME Shils (eds): *Modern Nutrition in Health and Disease*, 6th ed, Philadelphia, Lea and Febiger, 1980.

Table 112-6. Mineral mixture to complement liquid formulas

Salt	Amount, g	1 g mixture provides, meq	
KCl	44	K^+	8.5
NaCl	9	Na^+	3.5
Na_2HPO_4	7	Ca^{2+}	1.4
$CaCO_3$	5	Mg^{2+}	0.6
$MgSO_4 \cdot 7H_2O$	5	HPO_4^{2-}	1.4

clinicians worry about the possibility of lactose malabsorption in severe PEM. Recent studies [*28,29*], however, have shown that cow's milk is well-tolerated and assimilated by severely malnourished children and can be safely advocated. Eggs, meat, fish, soy isolates, and some vegetable-protein mixtures are also sources of good protein. Most vegetable mixtures have protein digestibilities that are 10 to 20 percent lower than animal proteins, making it necessary to feed larger amounts. Their bulk might pose a problem in feeding small children.

The initial response to diet is either no change in weight or a decrease due to loss of edema, accompanied by large diuresis. After some time, commonly 7 to 15 days, there is a period of rapid weight gain or "catch up." The rate of catch up usually is slower in marasmus than kwashiorkor. In children, this rate of weight gain generally is 10 to 15 times that of a normal child of the same age, and it can be as high as 20 to 25 times greater. Some patients only show a four- or fivefold increase in catch up; most times this is associated with insufficient energy intakes (formula inadequately prepared, insufficient amounts of formula given at each feeding, too few feedings per day, anorexia, or lack of patience of the person who feeds the child) or with overt or asymptomatic infections. Urinary infections and tuberculosis are among the most commonly seen asymptomatic diseases.

ENSURING NUTRITIONAL REHABILITATION

This last stage of treatment may begin in the hospital and continue on an outpatient basis, but making sure that the patient continues eating adequate amounts of protein, energy, and other nutrients, especially when traditional foods are introduced into the diet. Emotional and physical stimulation must be provided, and persistent diarrhea, intestinal parasites, and other minor complications must be treated. Children can be vaccinated during this period as well.

1. Introduction of Traditional Foods Other foods, especially those available at home, are gradually introduced into the diet in combination with the high-energy, high-protein formula. This should be done when edema has disappeared, the skin lesions are notably improved, the patient becomes active and interacts with the environment, appetite is restored, and adequate rates of catch-up growth have been achieved. A daily minimun intake of 3 to 4 g of protein and 120 to 150 kcal per kilogram of body weight (or more in marasmus) must be ensured. To achieve this, the energy density of solid foods must be increased with oil or fat, and protein density and quality must be high, using animal proteins, vegetable protein mixtures, or soybean protein concentrates and isolates. Local traditional foods can be used in appropriate combinations, *in addition to the liquid formula*, as in the following examples: (1) one part of a dry pulse or its flour (black beans, soybeans, kidney beans, cowpeas) and three parts of a dry cereal or flour (corn, rice, wheat); fat or oil should be added to the mashed or strained pulse during or after cooking, in amounts equal to the weight of the dry pulse or flour, and to the cereal preparations in amounts of 10 to 30 mL oil per 100 g dry cereal product, depending on the type of preparation. (2) Four parts of dry rice and two parts of fresh fish; fat or oil should be added in amounts equal to 20 to 40 percent of the dry weights. The foods can be served as separate dishes or they can be mashed or blended and fed as paps to infants and young children.

2. Emotional and Physical Stimulation The malnourished child needs affection and tender care from the beginning of treatment. This requires patience and understanding by the hospital staff and the relatives. Involvement of parents or relatives is usually very helpful. Hospitals should be brightly colored, cheerful, with audible stimulation such as music. As soon as the child can move without assistance and is willing to interact with the staff and other children, he or she must be encouraged to explore, to play, and to participate in activities that involve body movements. Relatively small increments in physical activity and energy expenditure during the course of nutritional rehabilitation result in faster longitudinal growth and accretion of lean body tissues [*12*].

Parents should be encouraged to stimulate and teach their children by playing and talking. Toys and play materials can often be made from discarded local articles.

3. Persistent Diarrhea and Other Health Problems Mild diarrhea does not interfere with nutritional rehabilitation, as long as fluid and electrolyte intakes maintain satisfactory hydration, and often disappears without specific treatment as nutritional status improves. Persistent diarrhea can contribute to the development of a new episode of PEM and should be treated. This is determined by the underlying cause of diarrhea, usually intestinal infections, excessive bacterial flora in the upper gut that ferment food substrates and deconjugate bile salts, intestinal parasites (particularly amebiasis, giardiasis, and trichiuriasis), and intolerance to food components. Among the latter, lactose, milk protein, and gluten have often been held responsible. This is often founded on inadequate diagnostic procedures (e.g., intolerance to 2 g lactose per kilogram in aqueous solution, rather than to the 7 to 15 g lactose contained in a milk meal) [*30*]. When food intolerance is suspected the diet should be modified, taking care to preserve its nutritional

quality and nutrient density. Before branding a patient as intolerant to a given food, it should be reintroduced into the diet to confirm the diagnosis and adequate diagnostic tests should be done.

4. Criteria for Recovery The most practical criterion is weight gain. A patient should be discharged from in-hospital or outpatient treatment when he or she has reached a body weight equal to or near the expected weight for height. A premature discharge increases the risk of a recurrence of malnutrition. If urine can be collected for 24 h in children, the creatinine-height index [26] can be used as an indicator of body protein repletion. Specific treatment of other nutritional problems (e.g., iron deficiency) must be prolonged beyond discharge for PEM.

When discharged, patients or their parents must be taught about the causes of PEM, emphasizing rational and nutritious use of household foods, personal and environmental hygiene, appropriate immunizations, and early treatment of diarrhea and other diseases.

Mild and moderate PEM

The less-severe forms of PEM should be treated in an ambulatory setting, supplementing the home diet with easily digested foods that contain proteins of high biological value and a high energy density. In some instances, therapy can be achieved merely by instructing the adult patient about adequate eating habits and a better use of food resources or by instructing mothers in improved child-feeding practices and in more nutritious culinary habits. It is almost always necessary, however, to provide both nutritious food supplements and instructions in their use.

The quantity of food supplements will vary depending upon the degree of malnutrition and the relative deficit of proteins and energy. As a general guideline, the goal should be to provide a total intake—including the home diet—of *at least* twice the protein and 1.5 times the energy requirements. For preschool children, this would signify a daily intake of about 2 to 2.5 g of high-quality protein and 120 to 150 kcal per kilogram of body weight, and for infants under 1 year, about 3.5 g protein and 15 kcal/(kg·day).

The ingestion of the food supplement by the malnourished person must be ensured. This is more likely to occur if it is appetizing to both the child and the mother, if it is ready-made or easy to prepare, if additional amounts are provided to feed the siblings, and if it does not have an important commercial value outside the home that would make it easy and profitable for the family to sell the item for cash. A substitution effect on the home diet (i.e., a decrease in the usual food intake) is almost unavoidable, but it can be reduced by using low-bulk supplements of high protein and energy densities. Special attention should be given to avoid a decrease in breast-feeding; the supplements for breast-fed infants should be paps or solid foods that will not quench the infant's thirst and thus not change the infant's demand nor the mother's attitude toward lactation.

Adequate amounts of vitamins and minerals must be assured, although mild deficiencies can be overcome by the micronutrients in the food or using fortified vehicles such as iron-enriched bread or sugar fortified with retinol.

POPULATION

The epidemiology of PEM is discussed in Chap. 23. Certain aspects, however, should be further emphasized.

POPULATION ECOLOGY

PEM can affect all age groups but it is more frequent among children whose growth increases nutritional requirements, and especially among the very young who cannot ensure adequate food intakes by their own means. Older children usually have milder forms of PEM because they can cope better with social and food availability constraints, because infections and other precipitating factors become less severe, and early survival may imply a natural selection of the more fit. Pregnant and lactating women can also have PEM but the consequences of the dietary deficiencies are seen mainly in the growth, nutritional status, and survival rates of their fetuses, newborn babies, and infants. Adult men and nonpregnant, nonlactating women usually have the lowest prevalence and the mildest forms of the disease, because of greater opportunities to obtain food and social and cultural practices that protect the productive members of the family.

Poverty, low food availability, and infectious disease stress are causes of PEM (see Chaps. 23, 24, 25). In some families or societies, ignorance may lead to poor infant- and child-rearing practices, misconceptions about the use of certain foods, inadequate feeding practices during illnesses, and improper food distribution within the family members. Poor environmental conditions favoring infections, and social problems such as child abuse, maternal deprivation, alcoholism, and drug addiction can lead to PEM in children and adults. Other circumstances that contribute to or precipitate PEM are agricultural patterns and climatic conditions leading to cyclic or sudden food scarcities, social and cultural practices which impose food taboos, the migration from traditional rural settings to urban slums, and a decline in the practice or duration of breast-feeding.

A profile of risk factors can indicate which individuals or societies are more prone to PEM. Thus, the most likely victims are children under 2 years of age from low socioeconomic strata whose parents have a series of misconceptions concerning the use of foods, whose families are known to have a high prevalence of alcoholism and unstable marriages, who live under poor sanitary conditions in urban slums or in rural areas

frequently subject to droughts or floods, and whose societal beliefs prohibit the use of many nutritious foods.

PREVENTION AND CONTROL OF PEM

Measures that will prevent the recurrence of PEM or the appearance of new cases include the availability and rational use of foods that optimize nutrient utilization, the control or reduction of infections, and health and nutrition education programs for the individual, the family, and the community.

Food availability

Inadequate food availability caused by poverty, cultural customs, cyclical climatic conditions, and natural disasters and those of human origin is a major constraint in the control of malnutrition. The solution of some conditions is dependent on social and economic changes while others, as natural disasters, are beyond human control. However, the pediatrician, nutritionist, public health worker, and educator can and *must* play an active role in ameliorating or solving other conditions.

Animal foods are the best protein sources but they tend to be expensive, not always available, or prohibited by religious practices. Under such circumstances, the staple foods can be complemented or substituted with vegetable foods combined in ways to permit a good essential amino acid complementation and improve the biological value of dietary protein. For example, corn and black bean combinations that provide proteins in a proportion of about 60:40, equivalent to about three parts of dry corn and one part of dry beans, have an excellent amino acid composition and permit adequate growth and function [*9,33*]. The same is true of a series of combinations of grains and/or legumes [*6*]. The relatively low nitrogen digestibility of these vegetable sources must be considered in recommending the amounts to be eaten. Energy density can be increased by adding fats or carbohydrates.

It will often be necessary to convince parents about the safety of using foods which, in some cultures, are fed only to adults and older children. This is especially true in the case of weaning foods. Trials at INCAP have shown that it is feasible to feed pablums based on legumes, a cereal, and vegetable oil to babies as young as 3 months without intestinal discomfort and without decreasing breast-milk intakes. Examples of such paps are shown in Table 112-7. Promotion of breast-feeding must accompany the recommendation for weaning foods.

Table 112-7. Paps to complement breast milk, using common foods and based on combinations of a legume, a grain, and vegetable oil

	A	B	C	D
Cooked beans*	25 g	20 g	20 g	25 g
Vegetable oil	12 g	7 g	7 g	10 g
Corn dough†	20 g	—	—	—
White bread‡	—	10 g	—	—
Boiled rice	—	—	22 g	—
Boiled potatoes	—	—	—	31 g
Protein, g/100 g§	5.6	7.1	6.1	5.5
Energy, kcal/100 g§	312	268	269	232

*Black beans (*Phaseolus vulgaris*), cooked and strained according to Guatemalan customs.
†Cooked, lime-treated corn dough.
‡Moistened with about 50 percent water.
§Protein and energy content of 100 g of pap, ready to eat.
Source: From F.E. Viteri, B. García, B. Torún, unpublished observations.

Reduction of morbidity rates

This is a logical consequence of the interactions of nutrition with infection. Since young children are at higher risk of malnutrition, high priority must be given to immunizations, sanitary measures to reduce fecal contamination, and early oral rehydration of children with diarrhea [*34*].

Education

The presence of a malnourished child in a family suggests that other members of the household might also be at risk of malnutrition. Therefore, nutritional and health education must not be restricted to the rehabilitation of the index case, but to prevention of nutritional deterioration of other family members, especially siblings and pregnant and lactating women. Similarly, a high prevalence of children with malnutrition or growth retardation indicates that the entire community is at some risk of impaired nutrition. Consequently, education programs must be devised for community leaders, civic action groups, and the community as a whole. Such programs must emphasize promotion of breast-feeding, appropriate use of weaning foods, nutritional alternatives using traditional foods, personal and environmental hygiene, feeding practices during illness and convalescence, and early treatment of diarrhea and other diseases. Personal and communal involvement should be pursued through commitments to apply the recommendations. Toward this aim, it is very important that all educational programs incorporate the people's own assessment of their nutritional problems and their feelings toward personal participation to contribute to the solution.

REFERENCES

1 Winick M, Nobel A: Cellular response in rats during malnutrition at various ages. J Nutr 89:300–306, 1966
2 Winick M, Rosso P: Brain DNA synthesis in protein-calorie mal-

nutrition, in Olson RE (ed): *Protein-Calorie Malnutrition*. New York, Academic, 1975, pp 93–102
3 Brożek J (ed): *Behavioral Effects of Energy and Protein Deficits*. Washington, D.C., NIH Publ No. 79-1906, 1979
4 Brożek J: Nutrition, brain and behavior, in Harper AE, Davis GK (eds): *Nutrition in Health and Disease and International Development*. New York, Alan R Liss, 1981, pp 371–382
5 Bengoa JM: The state of world nutrition, in Recheigl M (ed): *Man, Food and Nutrition*. Cleveland, Chemical Rubber Company, 1973, pp 1–14
6 Torún B, Young VR, Rand WM (eds): *Protein-Energy Requirements of Developing Countries: Evaluation of New Data*. Food Nutr Bull, suppl 5, 1981, 268 pp
7 Protein and energy requirements: A joint FAO/WHO memorandum. Bull WHO 57:65–79, 1979
8 Torún B, Young VR: Interaction of energy and protein intakes in relation to dietary requirements, in Harper AE, Davis GK (eds): *Nutrition in Health and Disease and International Development*. New York, Alan R Liss, 1981, pp 47–56
9 Viteri FE, Torún B, Arroyave G, et al: Use of corn-bean mixtures to satisfy protein and energy requirements of preschool children. Food Nutr Bull, suppl 5:202–209, 1981
10 Viteri FE, Alvarado J, Luthringer DG, et al: Hematological changes in protein-calorie malnutrition. Vitam Horm 26:573–615, 1968
11 Rutishauser IHE, Whitehead RG: Energy intake and expenditure in 1–3-year-old Ugandan children living in a rural environment. Br J Nutr 28:145–152, 1972
12 Viteri FE, Torún B: Nutrition, physical activity and growth, in Ritzén M et al (eds): *The Biology of Normal Human Growth*. New York, Raven Press, 1981, pp 265–273
13 Viteri FE, Torún B: Ingestión calórica y trabajo físico de obreros agrícolas en Guatemala: Efecto de la suplementación alimentaria y su lugar en los programas de salud. Bol of Sanit Panam 78:58–74, 1975
14 Waterlow JC: Adaptation to low-protein intakes, in Olson RE (ed): *Protein-Calorie Malnutrition*. New York, Academic, 1975, pp 23–35
15 James WPT, Hay AM: Albumin metabolism: Effect of the nutritional state and the dietary protein intake. J Clin Invest 47:1958–1972, 1968
16 Reddy V: Protein-energy malnutrition: An overview, in Harper AE, Davis GK (eds): *Nutrition in Health and Disease and International Development*. New York, Alan R Liss, 1981, pp 227–235
17 Patrick J: Death during recovery from severe malnutrition and its possible relationship to sodium pump activity in the leucocyte. Br Med J 1:1051–1054, 1977
18 United States Department of Health, Education and Welfare: *NCHS Growth Curves for Children from Birth to 18 Years*. Hyattsville, DHEW Publication PHS 78-1650, 1977
19 Gómez F, Ramos Galván R, Frenk S, et al: Mortality in second and third degree malnutrition. J Trop Pediatr 2:77–83, 1956
20 Waterlow JC: Classification and definition of protein-energy malnutrition, in Beaton GH, Bengoa JM (eds): *Nutrition in Preventive Medicine*. Geneva, World Health Organization, 1976, pp 530–555
21 Graham GG: The later growth of malnourished infants; effects of age, severity, and subsequent diet, in McCance RA, Widdowson EM (eds): *Calorie Deficiencies and Protein Deficiencies*. London, Churchill, 1968, pp 301–316
22 Jelliffe DB, Jelliffe EFP: The arm circumference as a public health index of protein-calorie malnutrition of early childhood: XX. Current Conclusions. J Trop Pediatr 15:253–260, 1969
23 Arnhold R: The QUAC stick: A field measure used by the Quaker Service Team, Nigeria. J Trop Pediatr, 15:243–247, 1969
24 Kanawati AA, McLaren DS: Assessment of marginal malnutrition. Nature 228:573–575, 1970
25 Nichols BL, Alvarado J, Hazlewood CF, et al: Significance of muscle potassium depletion in protein-calorie malnutrition. J Pediatr 80:319–330, 1972
26 Viteri FE, Alvarado J: The creatinine-height index: Its use in the estimation of the degree of protein depletion and repletion in PCM children. Pediatrics 46:696–706, 1970
27 Chen LC, Chowdry AKMA, Huffman SL: Anthropometric assessment of energy-protein malnutrition and subsequent risk of mortality among preschool aged children. Am J Clin Nutr 33:1838–1845, 1980
28 Solomons NW, Torún B, Caballero B, et al: The effect of dietary lactose on the early recovery from protein-energy malnutrition I: Clinical and anthropometric indices. Am J Clin Nutr, in press
29 Torún B, Solomons NW, Caballero B, et al: The effect of dietary lactose on the early recovery from protein-energy malnutrition. II. Indices of nutrient absorption. Am J Clin Nutr, in press
30 Torún B, Solomons NW, Viteri FE: Lactose malabsorption and lactose intolerance: Implications for general milk consumption. Arch Latinoamer Nutr 29:445–494, 1979
31 Whitehead RG: Infection and the development of kwashiorkor and marasmus in Africa. Am J Clin Nutr 30:1281–1284, 1977
32 Mata LJ: *The Children of Santa María Cauqué: A Prospective Field Study of Health and Growth*. Cambridge, Mass, MIT Press, 1978
33 Torún B, Viteri FE: Energy requirements of preschool children and effects of varying energy intakes on protein metabolism. Food Nutr Bull supp 5:229–241, 1981
34 Keusch GT, Katz M (eds): Effective interventions to reduce infection in malnourished populations. Am J Clin Nutr 31:2035–2126, 2202–2356, 1978