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Nutrition treatment in pediatric burns patients

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ABSTRACT

Burn trauma causes obvious pathophysiological disorders that potentially affect the organ systems. For this reason, there are specific nutrient needs that require aggressive food intervention after burns. Nutritional support in burn patients differs from general intensive care patients. The nutritional support to be applied during the hospitalization process is changed and even changed according to the developments during the disease period. Therefore, a multidisciplinary approach must be provided for patient nutritional support planning. Nutritional support of pediatric burn patient is one of the important issues in the continuity of care. Early nutrition support is widely accepted as a standard of care. Estimating calorie needs remains a poorly defined science, and direct measurement is often impractical. Enteral nutrition, both safety concerns and care, are the preferred route for the benefits of intestinal mucosal integrity. Additional substances and pharmacological agents have been advocated by some people, but there is no consensus on their routine use. The clinician should still pay attention to reasonable judgment and the overall progress of the patient to maximize results. With the use of aggressive resuscitation, nutritional support, infection control, surgical treatment and early rehabilitation, as well as multidisciplinary collaboration, better psychological and physical outcomes can be achieved for burn children.

Keywords: Burn, enteral nutrition, nutrition, pediatric burn unit, parenteral nutrition

Tissue damage caused by factors, such as heat, electricity, chemicals, boiling water, and flame is termed “burns.” The skin is not the only place that is affected by burns; it is a trauma that affects the whole body. The extent of tissue damage caused by the burn varies, depending on the size of the burned area and the continuity of the factor causing the burn.

Wounds resulting from burns are grouped as per the width and depth of the burn (1).

First-Degree Burns or Superficial Burns: They are painful and appear red. Vesicle and bulla formation is not observed. They heal spontaneously. Light sunburns without blistering are the best example of first-degree burns. First-degree burns are not considered significant and are not considered for the calculation of the burn surface area for fluid resuscitation. The use of these areas in fluid resuscitation is one of the most important reasons for excessive fluid delivery (2).

Second-Degree Burns: In cases where the thermal damage extends to the dermis, a second-degree burn develops. These burns are classified as superficial and deep second-degree burns. Superficial second-degree burns are painful bullae from which serous fluid leaks develop. The wound is usually pink or splotchy red and blanches on pressure application. If infection does not develop, these wounds heal within 10-20 d without or with very little scarring. Fluid resuscitation and monitoring may be needed for superficial second-degree burns that exceed 20% of the total body surface area (TBSA). Deep second-degree burns are drier and redder. They blanch slightly when pressure is applied and are less painful. They usually heal with a combination of wound contraction and re-epithelization; however, there is commonly a significant degree of scar contraction (2).

Third-Degree Burns: These burns are full-thickness burns. All layers of the skin are destroyed, and the skin looks charred, leathery, or waxy. Third-degree burns are usually dry accompanied by loss of sensation. Damage and injury can extend to the muscles and deeper tissues. They are normally caused by flame, immersion in very hot water, electric current, or chemical agents. Partially smaller full-thickness burns eventually heal spontaneously with contraction; however, this always results in severe deformity and function loss (2).

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The cause of burn can be thermal, electrical, chemical, or radiation. Each type of burn is associated with unique results that may require specific treatment. In wars, serious burns can occur on the battlefield owing to flame weapons, burst of explosives, and ignition of flammable materials. In addition, 3%–10% of the burns in children are caused by non-accidental causes. Child abuse may also be one of the causes, and attention should be paid to identify cases of child abuse because 30% of children who are exposed to repeated abuse die because of it (2).

Metabolic Changes in Burn

The onset of the burn syndrome or the ebb response (1st phase) is short and occurs 3–5 d after injury. This phase is characterized by general hypermetabolism and is manifested by a decrease in oxygen consumption, cardiac output, blood pressure, and body temperature. Fluid resuscitation is performed in this period in response to large fluid losses that occur in the early period after the burn. There is substantial increase in the catabolic hormone production as well as oxygen consumption after the 1st phase, with a peak between the 6th and 10th d after the burn. Thereafter, the metabolic rate begins to decrease slowly, and catabolism gradually regresses. These metabolic and hormonal sequelae have important effects from a nutritional perspective.

With the resuscitative repair of the circulating blood volume, the body progresses to prolonged hypermetabolism and increased nutrient turnover this stage is called the flow phase (2nd phase). This second phase is affected by increased levels of catecholamines, glucocorticoids, and glucagon in the circulation. Insulin levels are usually within the normal range in this period. However, with the increase in the glucagon/insulin ratio, other hormonal imbalances initiate gluconeogenesis, lipolysis, and protein degradation (3).

Preventing infection and reducing the wound size decreases the metabolic rate. Adequate pain and anxiety control also helps metabolism (4, 5). In Figure 1 below, the metabolic responses in burn trauma are depicted schematically (6).

CHO Metabolism

One of the metabolic changes that occur after thermal injury is carbohydrate metabolism disorder. Glycosuria and hyperglycemia often occur as an early response to burns. The

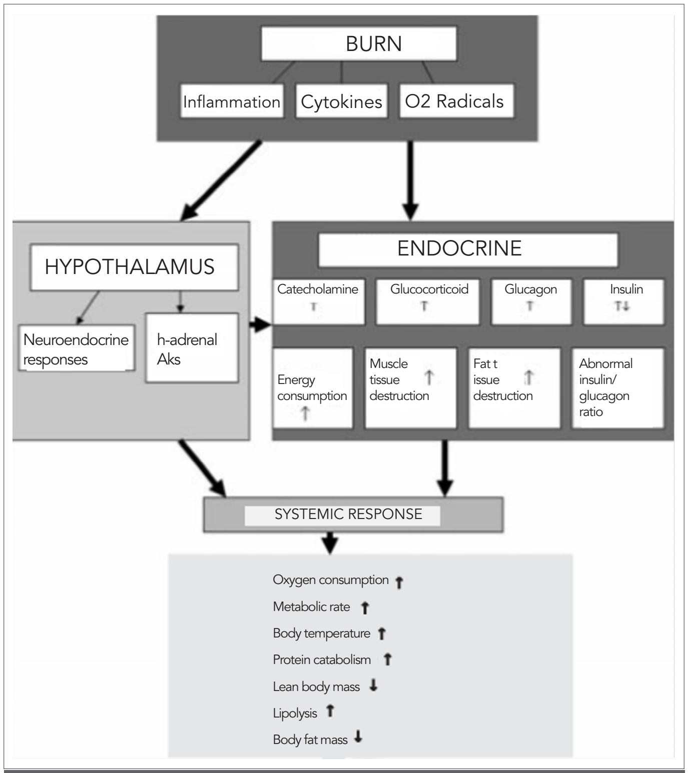

Figure 1. Stress response developing after burn injury (6)

Main Points

- In cases where oral nutrition is insufficient, enteral nutrition should be tried first in order to ensure the integrity of the intestinal mucosa. In terms of refeeding syndrome and existing impaired CHO metabolism, parenteral nutrition should not be preferred unless they are in a difficult situation.
- Most tube-feeding methods can be started at full dose. The initial hourly infusion rate should be started at about half of the desired final volume and increased, considering tolerance to 5 mL/h for infants and play-age children and 10 mL/h for school-age children, and at 20 mL/h for adolescents until the final hourly target rate is reached.
- Commercial infant formulas are traditionally used in enteral protocols specific to infants aged <6 mon. Normal dilution of baby food is 20 kcal/30 mL. It is safe to increase the concentration gradually to 24 kcal/30 mL. The baby should be closely monitored while increasing the energy intake to 27–30 kcal/30 mL to fulfill the needs of the baby owing to the increased renal solute load.
- Tube -feeding products for children aged >6 mon are selected from adult formulas containing 30 kcal/mL energy. If the protein content of the selected product is low, the product should be supported with protein modules such that 25%–30% of the energy content is protein.
- Glucose intake at 5–7 mg/kg/min is safe and effective while minimizing PN complications.
- Glutamine: While the positive effects of addition of 0.25–0.50 g/kg/d were observed in some studies, some studies showed that the plasma glutamine level increased and wound healing accelerated after 0.3 g/kg/d enteral glutamine use for 10 d.
- Arginine: Its use is not recommended in the absence of any conclusive study.

susceptibility to glucose intolerance is related to the burn severity. Moreover, the increase in blood sugar is modulated by the injury phase. During the shock phase, the main cause of hyperglycemia is impaired tissue perfusion and decreased use of glucose by the peripheral tissues rather than low insulin levels (7, 8) Glucose intolerance usually continues during the flow phase. (7) Exogenous insulin administration is often needed to improve blood glucose levels and achieve maximum glucose utilization (9-12).

Gluconeogenesis significantly increases after burns. Stress-related diabetes can occur because this increased production results in more glucose than that the tissues require. The source of glucose production is doubled (13).

Protein Metabolism

The protein requirement of a pediatric burns patient increases because of increased tissue destruction, rapid repair, and losses during growth. Inability to meet the increasing protein requirement results in delayed wound healing and reduced infection resistance. Further, the patient adapts to insufficient protein intake by reducing cell growth and compromising his/her genetic potential (3).

In case a high-protein diet is given, wound healing is enhanced, infection rates decrease, excess protein catabolism in the muscle decreases, and survival improves (13). However, the protein intake needs to be closely monitored because protein overload or amino acid imbalance can cause azotemia, hyperammonemia, or acidosis. Excessive protein intake may exert adverse effects on immature and impaired kidney functions (increased solid load) (13, 14) therefore, protein-rich formulas should not be given to children aged <1 y (3).

However, as per a recent study, more than the recommended amount of protein is safe and beneficial in young children with extensive burns and infants who have not started walking. In pediatric burns patients aged <3 y, consumption of protein equivalent to 23% of energy shortens the length of hospital stay prominently (13, 14).

Fat Metabolism

During the second phase (flow phase), the burn-mediated increase in the catecholamine and glucagon levels accelerates fat metabolism and oxidation. Fats are crucial in the diet of pediatric burns patients because of their high-energy density, their role in myelization of nerve cells, their contribution to brain development, their role in flavoring of foods, and the transport of fat-soluble vitamins (3).

Burns patients may experience irregularities in the body's ability to use lipids. Excessive dietary burns may delay recovery in burns patients. Complications of excessive fat consumption include lipidemia, fatty liver, diarrhea, and reduced resistance to infections (3).

Determination and Evaluation of Nutritional Status

Regular evaluation of the nutritional status is an essential element of post-burn nutritional therapy. The most important goal of successful treatment is to fulfill the energy and protein requirements of the patient (from all sources). Further, thermal damage affects several organ systems; therefore, evaluation parameters used in other types of trauma may not be appropriate in burns patients (4).

The following nutritional tests are used to determine the patients' nutritional status: Screening Tool for the Assessment of Malnutrition in Pediatrics, Screening Tool for Risk on Nutritional Status and Growth (Strong-kids), Pediatric Yorkhill Malnutrition Score (PYMS)-UK, and Subjective Global Nutrition Assessment. In addition to these tests, growth curves are used for assessing the nutritional status (15).

Weight monitoring and other anthropometric measurements: Weight loss of 5% in the first month and 10% in the first 6 months indicated malnutrition in critically ill children. However, leaks in body fluids, improper amount of fluid replacement, dressings, mobilization impairments, diuresis, or edema because of capillary leakage are factors that may mislead weight monitoring and other anthropometric measurement methods in pediatric patients (15).

Prealbumin level is the most preferred parameter in burns trauma owing to the possibility of decreasing plasma albumin levels because of fluid leaks or excessive fluid replacement. Prealbumin is less affected by liver and kidney function changes and fluid replacement than other serum proteins, and protein is an important parameter that indicates malnutrition because of its short half-life (16). A prealbumin level of approximately 15 mg/dL indicates early malnutrition and the need for initiating nutritional support (17). In Table 1 below, we present the reference intervals of prealbumin and albumin levels (6).

Another method for evaluating malnutrition is the monitoring of the nitrogen balance. This can be done by exam-

Table 1. Prealbumin, and albumin protein status in pediatric patients (6)

Prealbumin (mg/dL)		Albumin (g/dL)	
Normal	Deficiency	Normal	Deficiency
14–43	<10	3.0–5.4	<2.5

Table 2. Anatomical and physiological underdevelopments in children of various ages (3)

System	Deficiency	Clinical Reflection	Maturity Age
Temperature regulation	Labile system Surface area to body weight ratio increased considerably	Increased radiant and evaporative fluid loss Increased metabolic rate to maintain temperature	10–12 y
Skin	Thin skin	Heat penetrates faster and deeper burns develop	16–18 y
Gastrointestinal	Unmatured system Restricted surface area in the small intestine mucosa Decreased gastric volume capacity	Restricted digestion of some nutrients Tendency to antigen absorption High incidence of diarrhea	1–2 y
Renal	Glomerular underdevelopments Excretion of other sodium chlorides and other ions is insufficient as in water resorption in young kidneys.	Renal concentration ability is reduced. Therefore, more water is needed to eliminate the kidney solute load produced by protein and electrolyte metabolism.	1–2 y

Table 3. Common formulas used to calculate the calorie needs of burn patients (23)

Pediatric Formulas	kcal/day	Comments
Galveston	0-1 year 2100 (body surface area) +1000 (body surface area x TBSA)	Focuses on maintaining body weight
	1-11 year 1800 (body surface area) +1300 (body surface area x TBSA)	
	12-18 year 1500 (body surface area) +1500 (body surface area x TBSA)	
Curreri junior	<1 year Recommended dietary allowance + 15 (TBSA)	Commonly overestimates caloric needs
	1-3 year Recommended dietary allowance + 25 (TBSA)	
	4-15 year Recommended dietary allowance + 40 (TBSA)	

TBSA: total body surface area

ining the urea nitrogen level, considering the nitrogen lost from the wound site (15).

Protein turnover measurement with labeled phenylalanine, another parameter used for monitoring the nutritional status, gives precise results; however, it is not preferred owing to its high cost (6).

Planning of discharge should include the determination of the patient's oral intake, meeting and provision of nutrient requirements, and outpatient follow-up. The patient should be followed up for up to 12 mon after discharge (18).

Medical Nutrition Treatment

The purpose of providing nutritional support to pediatric burn patients is to facilitate wound healing, increase immunocompetence, restore organ function, and provide sufficient energy and nutrients to prevent the loss of lean tissue mass. Special care is taken when fluid restriction, organ failure, septicemia, mechanical ventilation, or any other existing condition limits the body's ability to absorb vital nutrients.

Weight Monitoring

Weight gain is important for pediatric patients for continued growth and development. The child's weight should be monitored as per age- and sex-specific standard growth curves (19).

Owing to their dynamic growth and physical activities, children need more energy per unit weight than adults. Although the intake of insufficient calories is harmful, consumption of too many calories is also associated with an increased metabolic rate, hyperglycemia, liver dysfunction, and increased carbon dioxide production (19).

Small burns that cover <20% of the surface area and are not accompanied by superficial injury, psychological problems, respiratory distress, and pre-burn malnutrition are generally supported by oral diets containing high protein and high-energy snacks.

In pediatric patients with burns that cover >20% of the surface area, the patient may not meet their nutritional needs only with oral intake. The enteral route is preferred over intravenous (IV) feeding (20).

Energy Needs

The complex metabolic difficulties that occur in burn injuries have a direct relation with the subsequent morbidity and mortality. Pediatric burn injuries have a high mortality rate (21). Older children are more metabolically and physically similar to adults than younger children. Therefore, they respond faster to treatment. However, younger age groups need special nutritional support due to anatomical and physiological immaturity (22). In Table 2 below, we can see the anatomic and physiological development ages in children (3).

Burns patients are hypersensitive to diarrhea, dehydration, and malnutrition; this increases the degree of catabolism. In the acute phase after the burn, the energy requirement for activity decreases greatly. The large number of formulas available for calculating the energy requirement is an indication of the uncertainty in this approach. For energy calculation, information about body weight, age, and burn area is required. Although these 3 factors predominantly affect the metabolic rate, energy expenditure is also influenced by factors, such as operation, pain, anxiety, and sepsis. Excessive energy delivery should be avoided because it may increase the metabolic rate, hyperglycemia, liver disorders, and CHO consumption. In pediatric burn patients, indirect calorimetry is the ideal method for determining energy expenditure; however, it is not used in routine clinical practice owing to its high cost (3). In Table 3 and Table 4 below, we have schematically shown the formulas used to calculate the energy requirement in pediatric burn patients.

As a hypothetical example of energy requirement, it is calculated as "The daily calorie need of a 5-year-old male patient who weighs 20 kg and has 30% burns is calculated as 750 calories per day (30×20+[5×30])." (3)

Needs for Macronutrients (CHO, Protein, Fat)

Carbohydrate: The CHO ratio should be at least 60% of the total energy. Non-protein kilocalories and nitrogen balance should be 150: 1 (19).

Fats: Lipids should be used in the diet at a rate of 12%–15% of the total calories (25). To prevent omega-3 YA deficiency, the ratio of dietary energy from linoleic acid should be 2%–3%. This requirement can be easily achieved due to the high content of fat and linoleic acid in enteral support products and IV fat emulsions. The use of fat, especially linoleic acid, the source of immunosuppressive metabolites, is recommended to be used in moderation in children aged >6 mon with burns. It is recommended to provide a source of omega-3 YA (3).

Protein: As per recommendations, 20%–25% of the energy requirement of babies and children >6 mon of age who have burns that cover >30% of their TBSA should come from proteins. This value corresponds to a protein intake of 2.5–4.0 g/kg/d (6) and a non-protein energy/nitrogen ratio of 80:1. Assuming that sufficient energy is being consumed, another factor that affects the protein adequacy is the quality of dietary protein. As a result, intact (complete) whey protein is recommended (3). Protein supplements given in high amounts may increase the renal solute burden, especially in young children and the elderly. However, a recent study has shown that intake of more than the recommended amount of protein intake is safe and beneficial in young children and infants who have not started walking who have extensive burns. In burns patients aged <3 y, protein intake equivalent to 23% of the energy requirement significantly shortens the hospitalization stay (26).

Needs for Micronutrients (Vitamin and Mineral)

The vitamin and mineral requirements increase with the severity of the thermal burn and are associated with the following:

- Increased protein synthesis,
- Increased energy expenditure,
- Increased micronutrient losses.

Table 4. Formulas for calculating the approximate nutritional needs in burn cases (24)

Formulas for calculating approximate nutritional needs in burn cases. Electronic archive study, 2010

Author	Gender	Formula
Harris&Benedict BMR	Male Female	Estimated Energy Requirements: BMR x Activity factor x Injur factor 66 + (13.7 x weight in kg) + (5 x height in cm) – (6.8 x age) 665 + (9.6 x weight in kg) + (1.8 x height in cm) – (4.7 x age) Activity Factors Confined to bed: 1.2 Minimal ambulation: 1.3 Injury Factors: <20% TBSA = 1.5 20-40% TBSA = 1.6 >40% TBSA = 1.7
Curreri	For all patients	Estimated Energy Requirements: (25 kcal x w) + (40 x % TBSA)
Pennisi	Adults Calories Protein Children Calories Protein	Estimated Energy Requirements: (20 x w) + (70 x %TBSA) (1 g x w) + (3 g x %TBSA) (60 kcal x w) + (35 kcal x %TBSA) (3 g x w) + (1 g x %TBSA)
Toronto Formula	For all patients	Estimated Energy Requirements: [-4343 + (10.5 x %TBSA + (0.23 x kcals) + (0.84 x Harris Benedict) + (114 x T (0C)) – (4.5 x days post-burn)] x Activity Factors Activity factors non-ventilated: Confined to bed: 1.2 Minimal ambulation: 1.3 Moderate act, 1.4 Ventilated-Depedent: 1.2
Modified Schofield	Men Women	Estimated Energy Requirements: BMR x Injury factor 10-18 yrs = (0.074 x w) + 2.754 18-30 yrs = (0.063 x w) + 2.896 30-60 yrs = (0.048 x w) + 3.653 60 yrs = (0.049 x w) 2.459 10-18 yrs = (0.056 x w) + 2.898 18-30 yrs = (0.062 x w) + 2.036 30-60 yrs = (0.034 x w) + 3.358 60 yrs = (0.038 x w) 2.755 Injury Factors: <10% TBSA = 1.2 11-20% TBSA = 1.3 21-30% TBSA = 1.5 31-50% TBSA = 1.8 >50% TBSA = 2.0
ASPEN	For all patients	25 a 35 kcal/kg/day
Ireton-Jones Formula	For spontaneously breathing patients Ventilated-Dependent	Estimated Energy Requirements: 629 – (11 x yrs) + (25 x w) – (609 x O) 1784 – (11 x yrs) + (25 x w) + (244 x S) + (239 x t) + (804 x B)

Table 4. Formulas for calculating the approximate nutritional needs in burn cases (24) (Continued)		
WHO	For Children Male <3 years Male 3 to 10 years Female<3 years Female 3 to 10 years	 (60,9 x weight in kg) – 54 (22.7 x weight in kg) + 495 (61 x weight in kg) – 51 (22.5 x weight in kg) + 499
Mayes	For Children Male & Female <3 years Male & Female 3 to 10 years	Estimated Energy Requirements: 108 + (68 x weight in kg) + (3.9 x %TBSA) 818 + (37.4 x weight in kg) + (9.3 x %TBSA)

kcals: calorie intake in past 24 hours; Harris Benedict: basal requirements in calories using the Harris Benedict formula with no stress factors or activity factors; T: body temperature in degree Celsius; Days post burn: the number of days after the burn injury is sustained using the day itself as day zero; w: weight in kg; yrs: age in years; S: male = 1 Female = 0; t: trauma present: 1 / No trauma present: 0; O: presence of obesity> 30% above IBW: 1 / absent:0; B: burn present = 1 / No burn present = 0

Table 5. Vitamin and mineral needs in burn patients (27)

Age (years)	Vitamin A (IU)	Vitamin D (IU)	Vitamin E (IU)	Vitamin C (IU)	Vitamin K (mcg)	Folate (mcg)	Cu (mg)	Fe (mg)	Se (mcg)	Zn (mg)
0-13										
Nonburned	1300-2000	600	6-16	15-50	2-60	65-300	0.2-0.7	0.3-8	15-40	2-8
Burned	2500-5000			250-500		1000[a]	0.8-2.8		60-140	12.5-25
≥13										
Nonburned	200-3000	600	23	75-90	75-120	300-400	0.9	8-18	40-60	8-11
Burned	10,000			1000		1000[a]	4		300-500	25-40

[a]Administered three times weekly

Individual vitamin and mineral requirements depend on the pre-burn condition of the patient.

Decreased gastrointestinal absorption, increased urine losses, altered distribution, and altered carrier protein concentrations after severe burns can cause several micronutrient deficiencies if not supported. In Table 5, we can see a schematic presentation of the vitamin and mineral requirements in pediatric burn patients (27).

- Disruptions in the electrolyte balance are common after severe thermal damage. It is necessary to monitor the serum sodium, potassium, chlorine, phosphorus, calcium, and magnesium levels several times a day. In the acute post-burn phase, electrolyte manipulation is mostly performed via the IV route.
- In addition to daily multivitamin intake and vitamin A, C, and D supplements, zinc intake is often necessary.
- Excessive bleeding is common after burns and burn surgery. In the postoperative period or during antibiotic therapy, IV vitamin K support at the therapeutic level may be beneficial.
- Oral, tube, and IV overfeeding often does not meet the increased micronutrient needs. Therefore, additional nutritional support should be provided to the patient.
- Thiamine, riboflavin, niacin, folate, biotin, vitamin K, magnesium, chromium, and manganese are cofactors in energy-dependent processes.
- Vitamin B12, folate, and zinc are cofactors in collagen synthesis.
- In addition to zinc, copper, and iron deficiency, the deficiency of many micronutrients, such as vitamin A, C, and E and pyridoxine may adversely affect the immune function.
- Iron supplementation may not be required because excessive iron intake increases the patient's susceptibility to infections (4).
- Owing to the presence of blistering wounds, losses and changes in metabolism, the needs for micronutrients increase in burn patients; thus, micronutrient intake is crucial to replace those that are lost. Daily multivitamin supplementation enriched with vitamin C and zinc is recommended (28).

- Zinc and copper supplementation may not be sufficient in children during hospitalization (29), and 30–220 mg/kg zinc sulfate (30), and 0.08 mg/kg copper sulfate supplementation is recommended (19).
- Vitamins and trace elements are frequently used in pediatric burns to support wound healing. Vitamin C takes contributes to collagen synthesis; vitamin A supports immunological functions and epithelization. A 1000-calorie enteral diet is recommended to contain 5000 IU of vitamin A (30).
- Research has shown that the blood levels of children remain below normal even if copper and zinc replacement is provided during hospitalization. In pediatric burns, supplements of 30–220 mg zinc sulfate and 0.08 mg/kg copper sulfate are recommended (29).
- Increasing reactive oxygen in the burn causes the antioxidant systems to decrease (31).
- The replacement of ascorbic acid, glutathione, carotenoids, and vitamins A and E decreases the irregularities secondary to burn, regulates microvascular circulation, and prevents the impairment of lipids by oxidizing (32).
- Children who have experienced major burns need to be given vitamin supplements in the form of multivitamins in addition to vitamin C, vitamin A, and zinc sulfate to ensure adequate wound healing. High doses of vitamin C (250–500 mg) and vitamin A (5000–10000 IU/d) were given to our burns patients during hospitalization (33).
- Pyridoxine requirement is closely associated to protein intake, diet, and protein metabolism (3).

Vitamin D Metabolism

Patients with burns have a high rate of demineralization because of several reasons, such as prolonged bed rest and long hospital stay, increase in glucocorticoids, and decrease in growth hormone; the high demineralization rate increased the risk of bone disease. The etiology of burn-related demineralization depends on many factors, some of which are prolonged bed rest, increased glucocorticoids, hypoalbuminemia, low cholesterol levels, and vitamin deficiencies (34, 35). The most effective method for treating this acute insufficiency is vitamin D3 supplementation. Furthermore, vitamin D deficiency affects bone growth and development in the long term, even during the recovery period, and may occur in pediatric burn patients (34-36).

In a study on a pediatric burns population, multivitamins containing 400 IU of vitamin D2 did not correct the vitamin D deficiency. Methods of dealing with calcium and vitamin D deficiency need to be investigated further (37).

Liquid Need

It is recommended to evaluate the tolerance and adequacy of BUN, plasma proteins, and nitrogen balance individually for assessing the fluid requirement. However, a high-protein diet is generally well tolerated by patients who have adequate fluid intake, do not have any renal or hepatic dysfunction, and have partially developed mediating metabolic pathways (3).

The change in capillary permeability causes fluid, electrolyte, and protein leakage from the vascular compartment around the burn wound into the interstitial space. Furthermore, the wound area loses its barrier ability for water evaporation. Owing to the high surface area per body weight, invisible fluid loss is critical in pediatric burns patients. Babies and young children are susceptible to insufficient fluid intake because compulsory urinary and invisible fluid losses are higher in children than in adults. Pediatric burns patients need more fluid per square meter of body surface area than adult burns patients (38). Adequate and rapid supply of fluid resuscitation preserves tissue perfusion and prevents organ system failure (37).

The most commonly used pediatric fluid replacement formula is the modified Parkland Formula for children (3). In Table 6 below, we have presented a schematic depiction of the nutritional rehabilitation stages in burn patients (39).

If the total burn width (TBW) is >10% of the TBW, intravenous fluid should be administered. The suggested formulas are recommendations and are only guidelines. They should be revised as per the clinical course of the patient. The following are recommended during the first 24 h:

- Galveston formula: 2000 mL/m^2 body surface+5000 mL/m^2 TBW, Lactated Ringer's solution. (Half of the calculated amount is given in the first 8 h, and the remaining half is administered in the subsequent 16 h).
- Patients with large burns or perineal burns who will be followed up closely should have a urinary catheter. The amount of urine to be removed per unit time should be 1–2 mL/kg/h) (The target urine density is 1015) (40).

More fluid than calculated is required in the presence of additional trauma, alcoholic patients, inhalation injury, delayed/insufficient fluid resuscitation, dehydration, and electrical burns (40).

Nutritional Support Systems (Enteral & Parenteral Nutrition)

Enteral feeding should be started as soon as possible in order to ensure the integrity of the intestinal mucosa and to increase the tolerance to tube feeding. The hypermet-

Table 6. Volume resuscitation in the first 24 hours (39)

	Formula Name	Solution	Volume in Firs 24 hr	Rate of Administration
Adult	Pakland	Lactated Ringer's	4 mL/kg/%burn	Over 8 hr, over 16 hr
	Modified Brooke	Lactated Ringer's	2 mL/kg/%burn	over 8 hr, Over 16 hr
Children	Shriners-Cincinnati	Lactated Ringer's	4 mL/kg/%burn + 1500 mL/m² BSA	Over 8 hr, over 16 hr
	Shriners-Cincinnati (for young pediatric patients)	Lactated Ringer's + 50 mcQ $NaHCO_3$ Lactates Ringer's 5% Albumin in Lactated Ringer's	4 mL/kg/%burn + 1500 mL/m² BSA	1st 8 hr 2nd 8 hr 3rd 8 hr
	Galveston	Lactated Ringer's	5000 mL/m² burn + 2000 mL/m² BSA	over 8 hr, Over 16 hr

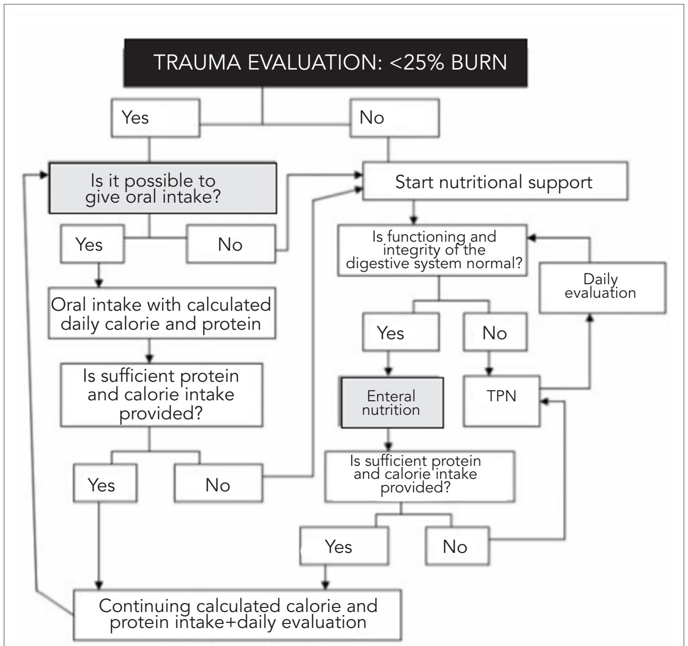

Figure 2. Algorithm of the Nutritional Support Methods in Burn Trauma (6)

abolic response is partially suppressed. Enteral nutrition passing the stomach and using the functional small intestine is preferred. The feeding tube placed in the third part of the duodenum is a safe tool because it provides enteral nutrition even in the case of patients with septic ileus. The protein content of infant formulas varies from 9% to 12% of the total energy requirement. This level is sometimes insufficient in patients with burns over a large surface area. A protein module may need to be added to the infant formulation with close monitoring. Soy formulas should not be used unless casein or whey protein intolerance has been confirmed in the patient. Fat is a vital nutrient during the maturation of the central nervous system; therefore, fat intake should not be reduced in infant burns patients (3).

Contraindicated situations for EN: Gastric nutrition cannot be used owing to reasons, such as the development of gastric ileus after burns that prevents the increase in the beginning of enteral nutrition and the delivery of full volume. In addition, NG increases the risk of aspiration because of various position changes such as feeding, changing clothes, physical therapy, and operation procedures. The patient feels minimal hunger during gastric feeding; therefore, oral intake is limited. In Table 7 below, we show the schematic presentation of the nutritional rehabilitation stages in burn patients (41).

External support given to patients to fulfill their energy, macronutrients, and micronutrients requirements by using their digestive systems is called enteral nutrition. The delivery of necessary nutrients via the intravenous route in patients whose digestive system cannot be used for nutrition delivery for various reasons is called parenteral nutrition. In Figure 2 below, we present the schematic algorithm of the nutritional support methods used for burn trauma patients (6).

Enteral Nutrition: It provides better regulation of inflammatory cytokine responses and may contribute less to immunosuppression following major surgery. Moreover, enteral feeding can decrease the intestinal permeability, protect the intestinal mucosal barrier, and exert a beneficial effect on reducing enterogenic infections (42). High calorie intake, mortality, sepsis, and pneumonia rates decreased significantly in patients. Although early EN is proven effective in burns patients, it is not associated with a decrease in the hypermetabolic response to burn wounds (14). Large amounts of protein intake with enteral support accelerate visceral protein synthesis and stimulate positive nitrogen balance and host defense factors. Early EN decreases the increasing energy deficit and stimulates insulin release while maintaining the lean

Table 7. Staged nutritional rehabilitation of severely malnourished burn patient (41)

	Stage 1: Days 0-2 asses and initiate	Stage 2: Days 3-7 achieve maintance	Stage 3: Days 7 and greater promote anabolism
Nutritional assessment	Anthropometrics/diet history • Obtain admission weight and Height • Clarify usual weight • Diet history prior to admission Biochemical measures • Electrolytes, glucose • Protein labs: CRP, Prealbumin, UUN Clinical observation • Wound status • Physical signs of wasting or malnutrition	Anthropometrics/diet history • Daily or biweekly weights • Daily intake and output • Daily calorie intake Biochemical measures • Frequent monitoring (every 4-6 h) of electrolytes • Fluid balance • Protein labs Clinical observation Monitor signs of refeeding syndrome • Tachycardia • Fluid retention • Shortness of breath	Anthropometrics/diet history • Weekly weight • Calorie counts • Dual energy X-ray Absorptiometry Biochemical measures • Electrolytes • Protein labs • Vitamin D work-up • Physical appearance / signs of weight gain • Donor site healing • Progress with physical therapy
Determination of nutritional requirements	Energy needs • REE by indirect calorimetry with slight factor for activity (1.2) • Predicted equation (BMRx1.3-1.75) Protein needs • 3-3.5 g protein/kg	Energy needs • Repeat indirect calorimetry • Adjust predicted stress factor per clinical factors Protein needs • Adjust protein needs based on protein labs	Energy needs • REE by indirect calorimetry with slight factor for activity (1.2) • Predicted equation (BMRx1.3-1.75) Protein needs • Adjust to support anabolism vs wound healing
Nutritional support	Slow initiation of feeds Enteral • Initiate 5-10 mL/h – advance every 6 h Parenteral • Begin 30% of goal volume rate	Achieve full feeds Enteral • Provide at goal rate. If unable to advance, begin parenteral Parenteral • Provide at goal rate; continue trophic feeds	Promote anabolism • Enteral feedings to meet weight gain goal; or • Allow oral intake with supplementary tube feeding overnight
Adjunctive nutritional pharmacology		May need to add micronutrient supplement	Add oxandralone or other anabolic agent

body mass. Polymeric products should be used in burns patients when digestion and absorption capabilities are intact. Elemental or dipeptide formulas are not generally required. Most tube feedings can be started at a full dose. The initial hourly infusion rate should be started at about 50% of the desired final volume and increased as per patient tolerance to 5 mL/h for infants and play-age children, 10 mL/h for school-age children, and 20 mL/h for adolescents until the final hourly target rate is reached (3).

Tube feeding may be terminated gradually as oral intake improves and nutrient requirements decrease. Tube feeding can be discontinued during meals to stimulate appetite in the beginning. Tube feeding may be required only during the night when the patient can obtain 20%–25% of his/her energy requirement by mouth. Thus, tube feeding can be terminated when 75% or more of the patient's energy requirement is being met with oral intake.

Includes tube feeding programs for pediatric burn patients:
- Suitable for children <6 months,
- Suitable for patients ≥6 months.

Commercial infant formulas are conventionally used in enteral protocols specific to infants aged <6 mon. Normal dilution of baby food is 20 kcal/30 mL. It is safe to increase the concentration gradually to 24 kcal/30 mL. The baby should be closely monitored while increasing the energy intake to 27–30 kcal/30 mL in order to fulfill the needs of the baby owing to increased renal solute load.

Tube-feeding products for children aged >6 mon are selected from among adult formulas containing 30 kcal/mL energy. If the protein content of the selected product is low, the product should be supported with protein modules such that 25%–30% of the energy is supplied from proteins.

No commercially available tube-feeding formula in the market is specifically designed for burn patients. However, this group of patients has atypical nutritional needs that exceed the conventional recommendations for high energy and high protein. With the modular tube, it offers the only way to combine recipes with only fat, amino acid, vitamin and mineral requirements (3).

The use of modular tube feeding is associated with a lower infection rate and shorter hospital stay. However, complex recipes may not always be applicable; therefore, it is recommended to evaluate the existing enteral products that are designed to be high in protein, low in fat, low in linoleic acid, and low in omega-3 acid as practical alternatives.

Due to the severe sedation and analgesia required by burn patients, delayed gastric emptying is common. In severe cases, post-pyloric feeding can be used to prevent energy deficiency during a long surgical procedure. Careful observation is necessary for prevention of pulmonary aspiration. Slow administration of pyloric or gastric support is better tolerated than bolus administration. Gastric suction can be performed simultaneously with the nasogenal feeding process. With the increased use of antibiotics and the administration of hyperosmolar products, diarrhea is a common complication of enteral feeding. During diarrhea episodes, if possible, at least some nutrients should be given enterally via trophic nutrition. However, constipation is also common in health centers that provide strong doses of opioids for sedation (25). Nutritional therapy should be improvised as per the symptoms observed in the patient.

CHO: Inappropriate carbohydrate replacement; While it causes protein catabolism by being inadequate to meet the increased need in the burn patient, excessive amount of carbohydrate may cause glucose to be stored as fat, glycosuria, polyuria, hyperglycemia, dehiscation and respiratory problems.. The administration of >7 mg/kg/min carbohydrate prevents its oxidization, and it is stored as fat (25).

Glucose homeostasis is an important parameter in children. In young children, hepatic glycogen stores are depleted after 12–14 h of fasting; thereafter, amino acids, glycerol, and lactate are used to create new glucose molecules. Therefore, it is vital to provide adequate glucose substrates during the first 24 h of resuscitation. This can be accomplished either by adding dextrose to the maintenance fluid or by providing early enteral feeding (grade C) (39).

Parenteral Nutrition: Parenteral nutrition is indicated in cases of gastrointestinal trauma, Curling's ulcer, severe pancreatitis, superior mesenteric artery syndrome, gastrointestinal system obstructions, severe vomiting and abdominal distension, persistent diarrhea, and necrotic intestine conditions; it is also indicated as an addition to insufficient enteral support (6).

If the essential YA requirement is met with trophic enteral nutrition, additional IV fat may not be needed. Patients for whom 100% of the energy requirement is fulfilled via the PN route need additional fat via the IV route. Giving 500 mL, 10% lipid emulsion (or 250 mL, 20% lipid emulsion) 2 or 3 times a week is sufficient to meet the essential YA requirement (6).

The PN right should only be applied to patients who cannot meet the requirements through EN because PN is associated with a large number of metabolic and mechanical complications and a high incidence of sepsis. Strict compliance to infection control standards and regular tolerance monitoring are required. Every attempt should be made to reduce PN to increase the EN ratio and subsequently reduce the risk of immunosuppression (6).

Glucose intake at 5–7 mg/kg/min is safe and effective, with minimum PN complications. As a patient recovers, his/her insulin resistance decreases, leading to improved glucose metabolism. This allows for a higher supply of glucose that is necessary for rehabilitation and growth (43).

Despite the advantages of total parenteral nutrition, there may be serious complications. Hyperglycemia, hyperkalemia, metabolic acidosis, thrombophlebitis, and cholestasis are the main complications. However, the most common complication is infection. Burns patients already have a

Table 8. Suggested pediatric total parenteral nutrition compositions (19)

Suggested Pediatric Total Parenteral Nutrition Compositions				
	Total Fluids (mL/kg/d)	Total Calories (kcal/kg/d)	Amino Acids (g/kg/d)	Fat (g/kg/d)
Infants	135–150	90–100	2–2.5	2–3
Children	60–80	70–100	1.5–2.0	1–2

Table 9. Commercially available pediatric enteral feeding (19)

Feeding	kcal/mL	PRO (g/mL)	Fat (g/mL)	CHO (g/mL)	Comments
Human milk	0.67	0.011	0.04	0.68	Easily digestible, low in calcium/phosphorus, vitamin D
Standard					
Enfamil	0.67	0.015	0.038	0.069	Contains palm oil that will decrease calcium absorption
Smilac	0.67	0.015	0.036	0.072	Contains nucleotides that increase immunity
Isomil	0.67	0.018	0.037	0.068	For cow protein allergy, lactose free
Prosobee	0.67	0.020	0.036	0.068	For cow protein allergy, lactose free
Special					
Alimentum	0.67	0.019	0.038	0.069	For generalized malabsorption
EleCare	0.67	0.020	0.032	0.072	For protein malabsorption
NeoSure	0.67	0.019	0.041	0.077	For former preterm infants <1 y old
PM 60/40	0.67	0.015	0.037	0.069	For renal or cardiac impairment
Pregestimil	0.67	0.019	0.028	0.091	For generalized malabsorption
Portagen	0.67	0.022	0.030	0.074	For long-chain fatty acid malabsorption
Smilac 2	0.67	0.014	0.037	0.071	For patients 9-24 mo old
SSC 30	1.00	0.030	0.067	0.078	Not to be used for infants >3.6 kg
Pediatric					
Compleat	1.00	0.038	0.039	0.013	Blend of traditional foods (chicken, fruits, etc.)
Kindercal	1.06	0.030	0.044	0.135	For ages 1-10 y, available with fiber
Pediasure	1.00	0.030	0.038	0.131	Comes with fiber, for ages 1-13 y
Vivonex	1.25	0.030	0.030	0.163	Free amino acids, semi-elemental

CHO: carbonhydrate; PRO: protein; SSC: Similac Special Care

higher susceptibility to infections, and the use of intravenous routes without strict adherence to aseptic practices further increase the infection risk. One of the complications that can be seen during TPN is refeeding syndrome. Although its etiology remains unclear, it is known to occur with more than required feeding. Abnormalities in the cardiovascular system and fluid and electrolyte balance are observed in this syndrome.

The use of PN with EN until the target EN is reached is not recommended because it is related to a significantly high mortality rate (14). In Table 8 below, we have presented the recommended total parenteral nutrition compositions in pediatric burn patients (19).

In Table 9 below, we can see the macronutrient contents of pediatric enteral nutrition products in the market schematically (19).

In Table 10 below, we have schematically shown the micronutrient contents of some pediatric products that are commercially available in the market (44).

Table 10. Selected presentations of the vitamin and trace elements available in the united states (44)

Age, y	Enteral	Parenteral
0-12	Enfamil Poly-Vi Sol (1 mL) Vitamin A: 1500 IU Vitamin D: 400 IU Vitamin C: 35 mg Vitamin E: 5 IU Vitamin A: <2 y, 2500 IU 2-12 y, 5000 IU Vitamin C: 250 mg Vitamin E: 5 mg Folic acid: 1 mg[a] Zinc sulfate: 50-110 mg	MVI Pediatric (5-mL vial) Vitamin A: 2300 IU Vitamin D: 10 mcg Vitamin C: 80 mg Vitamin E: 7 mg Folate: 140 mcg Vitamin K1: 200 mcg Multitrace-4 Pediatric (3 ml vial) Each mL provides: Zinc: 1 mg Manganese: 25 mcg Copper: 0,1 mg Chromium: 1 mcg Selenium (sodium selenite-10 mcg/mL)
≥12	Rx Choice Thera-Plus (5 mL) Vitamin A: 5000 IU Vitamin D: 400 IU Vitamin C: 35 mg Folic acid: 1 mg[a] Vitamin a: 10,000 IU Vitamin E: 10 mg Zinc sulfate: 200 mg	Infuvite Adult (5-mL vial) Vitamin A: 3300 IU Vitamin D: 200 mcg Vitamin C: 200 mg Vitamin E: 10 mg Folate: 6000 mcg Vitamin K1: 150 mcg Multitrace-4 Pediatric (10 mL vial) Each mL provides: Zinc: 1 mg Manganese: 100 mcg Copper: 0.4 mg Chromium: 4 mcg Selenium (sodium selenite-10 mcg/mL)

IU: International Units; mcg: micrograms; mg: milligrams; mL: milliliters.
[a]Administered Monday, Wednesday, and Friday

Immunonutrition

Immunonutrition has recently been an important research subject in the area of nutrition support for burn patients. In vitro studies and animal experiments have shown that these nutrients reduce the cytokine and inflammatory responses that develop after burn injury, positively affect wound healing, prevent excessive fat and muscle loss, and reduce the infection risk (45). Some studies have shown that immunonutrition is associated with increased mortality risk in intensive care patients (46, 47). Arginine and glutamine are accepted as essential amino acids due to the increased needs of patients with burns, depending on the conditions, the loss of high amount of amino acids from the burn wound, and the decreased efficiency of their production and use. Although studies have reported the positive effects of arginine on wound healing and protein balance in terms of reduced infection risk and antibiotic use in burn patients (48, 49), one study has demonstrated an increased risk of mortality with the use of arginine (50). Although glutamine is also reported to reduce the mortality risk, particularly by reducing infections in the blood (51), research has shown that glutamine is not beneficial in such patients (48).

Glutamine: Glutamine, the use of which has been studied extensively in burns patients, is a situationally essential amino acid for this patient group. Glutamine decreases the infection rate, increases the visceral protein levels, accelerates wound healing (52), and consequently lowers the mortality and hospital stay duration. The enteral route has been used in most studies on glutamine use in burns patients (53). While positive effects of the addition of 0.25–0.50 g/kg/d have been observed in some studies (18), other trials have shown that the plasma glutamine level increased after 10 d of 0.3 g/kg/day enteral glutamine use and the wound healing accelerated. The use of glutamine in burns patients was also included with A-level evidence in the guideline published by ESPEN in 2006 (53). In studies on the cost associated with glutamine administration, although glutamine-supplemented enteral products are more expensive than standard products, they are associated with a significant reduction in the total hospital costs (54).

Arginine: The adverse effects of arginine completely overshadow the positive effects stated in the literature, and these effects were particularly observed in patients with sepsis and pneumonia; therefore, arginine is not recommended for use in burn patients at present. Data from laboratory and clinical studies have shown that other branched-chain amino acids are ineffective in protein synthesis, immune functions, and general clinical course in burn patients. Therefore, the use of branched-chain amino acids is not recommended in burns patients (18).

Finally, research has indicated that diarrhea, infections, muscle mass loss, hospital stay reduction, and faster wound healing are enhanced with the addition of fish oil in the diets of burned patients. However, a definite conclusion cannot be drawn owing to insufficient researches on the subject (6).

Conclusion

Burn trauma potentially causes significant pathophysiological disorders that affect organ systems. Thus, there are nutritional needs specific to burns that require aggressive food intervention. Early continuous enteral nutrition with high calorie, protein, carbohydrate, and low fat is recommended for burns patients. In addition to multivitamin supplements, pharmacological doses of vitamins A and C and zinc are also indicated. Moreover, the comparison of the ongoing follow-up and nutritional care plan is essential for achieving the goals. Recent studies have focused on arginine and glutamine supplementation and determination of optimal lipid support. Moreover, studies on pharmacological intervention in metabolism and acceleration of wound healing are ongoing. Various nutrients are found beneficial in immunological functions after burns and in sequelae repair. While researches trying to determine the final nutritional regime to be applied after thermal damage continue, the most accurate recommendations regarding nutrient needs are expected (14).

In burn patients, early enteral feeding is the preferred route owing to the safety, care, and advantages in terms of intestinal mucosal integrity (42). Better psychological and physical outcomes for burn children can be achieved with the use of multidisciplinary collaboration and aggressive resuscitation, medical nutritional therapy, infection control, surgical treatment, and early rehabilitation (27).

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