Published in final edited form as:

J Surg Res. 2011 March ; 166(1): e83–e90. doi:10.1016/j.jss.2010.10.006.

ASSOCIATION BETWEEN DIETARY FAT CONTENT AND OUTCOMES IN PEDIATRIC BURN PATIENTS

Jong O. Lee, MD^{a,*}, Gerd G. Gauglitz, MD^{a,*}, David N. Herndon, MD^{a,b}, Hal K. Hawkins, MD, PhD^a, Stefanie C. Halder, MS^a, and Marc G. Jeschke, MD, PhD^{a,b}

^aShriners Hospitals for Children, University of Texas Medical Branch, Galveston, Texas

^bDepartment of Surgery, University of Texas Medical Branch, Galveston, Texas

Abstract

Background—The aim of the study was to compare a low fat/high-carbohydrate diet and a high-fat diet on clinical outcomes by a retrospective cohort study.

Methods—Nine-hundred forty-four children with burns >40% of their total body surface area (TBSA) were divided into two groups: patients receiving Vivonex[®]T.E.N. (low-fat/high-carbohydrate diet; n=518) and patients receiving milk (high-fat diet; n=426). Patient demographics, caloric intake, length of hospital stay and incidence of sepsis, mortality, hepatic steatosis and organomegaly at autopsy were determined.

Results—Demographics and caloric intake were similar in both groups. Patients receiving Vivonex[®]T.E.N. had shorter ICU stays (Vivonex[®]T.E.N.: 31±2 days; milk: 47±2 days; p<.01), shorter ICU stay per % TBSA burn (Vivonex[®]T.E.N.: 0.51±0.02 days/%; milk: 0.77±0.03 days/%; p<0.01), lower incidence of sepsis (Vivonex[®]T.E.N.: 11%; milk: 20%; p<0.01) and lived significantly longer until death than those receiving milk (Vivonex[®]T.E.N.: 20±3 days; milk: 10±2 days; p<0.01). There was no difference in overall mortality between the two groups (Vivonex[®]T.E.N.:15% vs. milk: 13%; p<0.9). Autopsies revealed decreased hepatic steatosis and decreased enlargement of kidney and spleen in patients receiving Vivonex[®]T.E.N.

Conclusions—The period with a low-fat/high-carbohydrate diet was associated with lower LOS, decreased incidence of organomegaly, infection, and hepatic steatosis post-burn as compared to the period when a high-fat diet was used. We suggest that a low-fat/high-carbohydrate diet should be considered in severely burned patients.

Keywords

VLDL; Free Fatty acids; Milk; Burns; Children; Nutrition

INTRODUCTION

The metabolic consequences of severe burns are profound and the modulation constitutes an ongoing challenge for successful burn treatment [1]. The release of inflammatory mediators and major hormonal changes lead to profound metabolic abnormalities post burn [1, 2]. Increased endogenous catecholamines causes augmented rates of protein catabolism and

Corresponding Author: Marc G Jeschke, MD, PhD, Ross Tilley Burn Centre, Sunnybrook Health Science Centre and University of Toronto, Department of Surgery, Division of Plastic Surgery, 2075 Bayview Avenue, Room D704; Toronto, ON, Canada M4N 3M5, Phone: (416) 480-6703; Fax: (409) 770-6919, majeschk@utmb.edu or Marc.Jeschke@sunnybrook.ca.

*Both authors contributed equally to this manuscript

This work was presented in part at the Society of Critical Care Medicine 36th Critical Care Congress, 2007, Orlando, Florida.

accelerate muscle proteolysis as well as increase lipolysis [3, 4]. Metabolic rates of burn patients can dramatically exceed those of other critically ill or trauma patients and cause marked wasting of lean body mass (LBM) within days after injury [2]. Hypermetabolism and catabolism of muscle protein continue up to six to nine months after a severe burn [5]. Failure to meet the subsequent large calorie and protein requirements may result in impaired wound healing, organ dysfunction, susceptibility to infection and death [5]. Thus, adequate nutrition is imperative for the treatment of severely burned patients. Nutritional support of the hypermetabolic response in severely burned patients can abate the hypermetabolic response to a burn.

Significant alterations in the metabolism of lipids, carbohydrates, and proteins determine the caloric distribution of the dietary needs of the critically ill patient. As essential fatty acid deficiency is a well-documented complication in hospital patients receiving long-term nutritional supplements, most intensive care units (ICUs) provide a significant amount of caloric requirements as fat [3]. This has been shown to reduce the requirements for carbohydrates and can improve glucose tolerance significantly, which is often altered in the patient after burn [5]. For these reasons, diets containing 30% to 50% fat have become commonplace in the therapy of critically ill patients throughout the world [5]. However, several studies showed that increased fat administration may lead to increased complications, including hyperlipidemia, hypoxemia, hepatic steatosis, a higher incidence of infection and a higher postoperative mortality rate in the burned patient population [6–8]. We, therefore, conducted a small-scale prospective study in 1996 and found that a low-fat/high-carbohydrate diet appeared to be beneficial for the outcome of severely burned children and consequently changed our nutrition protocol [9]. The aim of the present retrospective study, therefore, was to assess, in a large cohort of severely burned children, the effects of a low-fat/high-carbohydrate diet (Vivonex® T.E.N.) on morbidity and mortality when compared to a high-fat diet (milk).

MATERIALS AND METHODS

Nine-hundred forty-four severely burned children, admitted to the Shriners Hospitals for Children, Galveston, Texas, from 1985 to 2004, were included in this study. Permission for conducting the study was obtained from the Institutional Review Board of the University of Texas Medical Branch, Galveston, Texas.

The following inclusion criteria were used: children < 18 years of age, total body surface area (TBSA) burns > 40%, no signs of sepsis at admission and transfer to our institution within 72 hours post injury.

Study design

The potential beneficial effects of a low-fat/high-carbohydrate diet (Vivonex® T.E.N.) on clinical outcome of severely burned children were assessed in this retrospective cohort study. All subjects met the above mentioned inclusion criteria and were retrospectively divided into two groups, based on the following time periods:

- Patients receiving whole cow's milk (high fat) from 1985 to 1995 and
- Patients receiving Vivonex® T.E.N. (low fat) from 1996 to 2004

For all patients included in this study, a similar burn, feeding, and resuscitation protocol was utilized: Within 48 hours after admission, regardless of the day of the week, each patient underwent burn wound excision and grafting with either autografts or allografts. The patients returned to the operating room when donor sites for autograft had healed and became available for re-harvesting 6 to 10 days following the last operation. Sequential

staged grafting procedures were performed until the wounds were closed. Each patient received enteral nutrition via nasoduodenal or nasojejunal tubes in addition to oral intake to meet the caloric requirement. The daily caloric intake was calculated to deliver 1500 kcal per square meter of body surface area burned plus another 1500 kcal per square meter of TBSA [10–15].

Even though concentration of calories in both diets were different, both study groups received similar amount of calories after volumes of tube feeding were adjusted to provide same calories. In order to provide more calories, milk group received larger volume of feeding. The major differences in these diets were their concentrations of carbohydrates and fat: whole milk provides 30% of calories as carbohydrates and 49% as fat, while the Vivonex®T.E.N. (Sandoz Nutritional, Minneapolis, MN) has 82% of calories from carbohydrates and only 3% from fat (Table 1). These enteral formulas provide the caloric intake required to maintain body weight throughout the hospital course. Enteral nutrition was started at admission and caloric intake remained constant throughout the hospital stay. Once patients were started on oral intake, their caloric equivalent was subtracted from tube feeding until it was completely discontinued. Primary outcome measured was mortality. Secondary outcomes measured were length of stay in the ICU, sepsis, and hepatic steatosis.

Demographics

Age, burn size, gender, depth of burn, and time from burn to admission were collected for each group.

Length intensive care unit (ICU) stay, incidence of sepsis, infection and mortality

Length of intensive care unit (ICU) stay, presence or absence of inhalation injury, incidence of sepsis and mortality were recorded in each group. Sepsis was defined as a positive blood culture or pathological evidence of tissue invasion with $>10^5$ cfu/gm in combination with at least three of the following criteria: leukocytosis or leucopenia ($>12,000$ or $<4,000$), hyperthermia or hypothermia (>38.5 or $<36.5^\circ\text{C}$), tachycardia (>150 beats per minute in children), refractory hypotension (systolic BP <90 mmHg), thrombocytopenia (platelets $<50,000/\text{mm}^3$), hyperglycemia (serum glucose >240 mg/dl) and enteral feeding intolerance (residuals >200 cc/hr or diarrhea $>1\text{L/day}$) as previously published [16–19].

Autopsy

Autopsy results of one-hundred thirty-five who died out of nine-hundred forty-four severely burned children during the study period (milk, $n = 57$, vs. Vivonex®T.E.N., $n = 78$) were evaluated. One experienced pathologist, blinded to the samples, examined the liver of these patients macroscopically and microscopically for intracellular deposition of fat within hepatocytes. Congestion, edema, and necrosis of the liver parenchyma were also noted. Fatty metamorphosis (steatosis) of the liver, congestion, and necrosis were categorized as absent, mild, moderate, or severe. For statistical analysis of steatosis of the liver, rank values were assigned to all observations. All equal values were tied in rank, and an averaged rank was assigned to all tied values from low to high in a blinded fashion. The rank transform assigned integer values to data. We also determined kidney and spleen size at autopsy.

Statistics

Data are presented as means $\pm$ SEM. The distribution of the data was normal, and the degree of variation within individual subjects was similar. We did not control for differences between the groups in sex and age, but no significant differences were detected. Two-sided paired t-tests or ANOVA were used to compare data within groups. P values of less than

0.05 were considered to indicate statistical significance. Statistical analysis was carried out using SigmaStat for Windows (version 2.03, copyright SPSS, Chicago, IL).

RESULTS

Nine-hundred forty-four severely burned children were admitted during our study period (426 from 1985 to 1995 and 518 from 1996 to 2006). Patient demographics are shown in Table 2. Patients who received Vivonex®T.E.N. were of similar age, gender, ethnicity, burn size, size of third-degree burn and time from burn to admission when compared to patients who received milk.

Length of intensive care unit (ICU) stay and length of ICU stay per %TBSA burn

Patients in the Vivonex®T.E.N. group were found to have a significantly shorter stay in the ICU (31 ± 2 days) when compared to children receiving milk (47 ± 2 days), $p < 0.01$, (Figure 1A). Length of ICU stay per % TBSA burn was significantly decreased in children receiving Vivonex®T.E.N. (0.51 ± 0.02) when compared to those receiving milk (0.77 ± 0.03), $p < 0.01$, as shown in Figure 1B. Annual LOS for both groups over time is summarized in Figure 4B.

Sepsis and mortality

Patients receiving Vivonex®T.E.N. demonstrated a significantly lower incidence of sepsis (11%) when compared to children receiving milk (20%), $p < 0.01$, (Figure 2A). Patients receiving Vivonex®T.E.N. lived significantly longer until death than those receiving milk, $p < 0.01$. Specifically, Vivonex®T.E.N.-fed patients lived for 20 ± 3 days, while milk-fed patients lived for only 10 ± 2 days, as shown in Figure 2B and C. However, there was no difference in overall mortality between the two groups (Vivonex®T.E.N.: 15% vs. milk: 13%). Annual mortality and incidence of sepsis over time is summarized in Figure 4A and B, respectively.

Fatty metamorphosis of the liver

One-hundred thirty-five autopsies, performed in patients who died during the period studied, revealed significantly less hepatic steatosis in Vivonex®T.E.N.-fed patients when compared to patients receiving milk, $p < 0.01$. Only 19% of the autopsied patients in the Vivonex®T.E.N. group developed fatty metamorphosis of the liver, while 66% of those in the milk-fed group showed signs of hepatic steatosis (Figure 3A). Also, based on the macroscopic and microscopic examination of an experienced pathologist (all autopsies were conducted by the same experienced pathologist), average fatty metamorphosis of the liver of milk-fed patients was rated as moderate to severe while analysis of livers of Vivonex®T.E.N.-fed patients revealed mild fatty metamorphosis (data not shown).

We also determined kidney and spleen size at autopsy. We found that Vivonex®T.E.N.-fed patients who did not survive were found to have significantly lower spleen weights and kidney weights compared to milk-fed patients implying renal-splenomegaly in the milk group, $p < 0.05$, (Figure 3B and C).

DISCUSSION

Adequate nutrition is imperative in the treatment of severely burned patients. Different formulations have been developed to address the specific energy requirements of burned adult and pediatric patients [11, 12, 14, 20–22].

The purpose of this study was to assess, in a large cohort of severely burned children, the effects of a low-fat/high-carbohydrate diet (Vivonex®T.E.N.) on clinical outcomes when compared to a high-fat diet (milk). There have been prospective studies showing benefits of low fat diet in burn patients [6, 23].

Major hormonal changes in this patient cohort lead to increased lipolysis and consequently to enhanced production of free fatty acids [1, 24]. This increased rate of free fatty acid production is, however, not linked to increased oxidation of fatty acids as fuel [3, 25]. In fact, the majority of free fatty acids are re-esterified in the liver to triglycerides, potentially leading to fatty liver metamorphosis, progressive cholestasis and hyperlipidemia [3]. The extent to which triglycerides (TG) are produced and secreted into the blood in very low density lipoproteins (VLDLs) is also critical in determining net fat accumulation in the liver [26]. Livers of burn patients secrete less VLDL and this contributes significantly to TG accumulation in this organ [26]. Thus, the extent to which exogenous lipid can be utilized as an energy source after burn is considerably limited [1, 3, 24]. It therefore appears that fatty infiltration of various organs occurs by two mechanisms, increased peripheral lipolysis and due to the lack of transporter proteins accumulation in the organs.

Consistent with the above observations, patients receiving a low-fat/high-carbohydrate diet (Vivonex®T.E.N.) displayed considerably lower incidence of hepatic fatty metamorphosis upon autopsy when compared to milk-fed patients. Furthermore, these patients displayed significantly lower incidence of sepsis when compared to children receiving high-fat diet and had notably shorter stays in the ICU as well as significantly decreased length of stay in the ICU per % TBSA. An increased incidence of sepsis implies exhaustion and dysfunction of immunologic defenses in the milk-fed group, and may explain the significant enlargement of the spleen seen in the milk-fed group when compared to the Vivonex®T.E.N.-fed group.

Carbohydrates are utilized as a major energy source for critically injured patients. Increased carbohydrate intake during this period has been shown to be associated with higher endogenous insulin concentrations [9]. In Vivonex®T.E.N. group, higher concentration of carbohydrates may have resulted in higher glucose levels requiring more insulin administration which may have had anabolic effects in these patients.

Insulin has well described beneficial anabolic effects on muscle protein [19, 24]: it increases protein synthesis [4, 17] and inhibits protein breakdown [12, 27]. However, the hormonal environment of burn injury greatly increases proteolysis. Provision of carbohydrate and fat calories is only partially successful in reducing protein catabolism, since the latter cannot be synthesized from the former. Thus, a sufficient quantity of amino acids must be supplied to satisfy ongoing demands and provide proteins necessary for muscle assembly, wound healing, enzyme function and immune competence. In addition to its effects on protein metabolism, a high-carbohydrate diet may be beneficial in the post burn metabolic state, since it effectively suppresses lipolysis in children [26].

The major limitation of this study is that it is a retrospective analysis over a long period of time. During this time period, not only has nutrition changed but also the burn care. Burn care has significantly improved from 1985 to 2004, including surgical techniques, critical care, ventilator management with low tidal volume ventilation and use of PEEP, the use of tight glucose control, and adequate and focused antibiotic coverage. Furthermore, the use of anabolic agents and early mobilization further improved patient morbidity and mortality (Figure 4). All of these could have added to improved patient outcome. However, our data indicate that nutrition may have also contributed to improved patient outcome post-burn.

Other limitations of this study include lack of collection of certain parameters (e.g. weight, height) over time which would have added significant information. Third, the composition

of the diet varies not only in fat but also in other components. Vivonex®T.E.N. contains glutamine at 4.9 g/L. Glutamine has been shown to be organ protective and decreases the incidence of sepsis in burn patients [28]. Therefore, not only can fat be detrimental but glutamine could be organ-protective. However the amount of glutamine supplemented in multiple references for glutamine enhancement in burns are considerably higher. Wischmeyer et al. [28] used 0.57 g/kg/day of glutamine in their study of mostly adult patients with mean age of 30. Patients in Vivonex®T.E.N. group received less amount of glutamine than these other glutamine studies. Therefore, the degree of benefit from glutamine in Vivonex®T.E.N. is less likely than low-fat diet. The present study was not set up to answer this question and surely cannot differentiate whether improved morbidity post-burn was due to glutamine or low-fat content. However, based on the pathophysiologic principles, post-burn with dramatically increased lipolysis and free fatty acids, and based on the autopsy findings of increased fat content in all organs, we suggest that nutrition containing high-fat content is more detrimental than glutamine is protective. We believe, however, that glutamine could be beneficial in burn patients and a prospective multicenter trial should be conducted to determine the effects of glutamine on burn patient outcome.

Epidemiologic data suggest that hepatic steatosis may increase the risk of infectious complications [29]. Immediately after burn, liver damage is associated with increased hepatic edema, followed by cell damage and hepatocyte cell death [30]. In our burn rodent model, we have shown that thermal injury induces significant increases in serum and hepatic concentrations of pro-inflammatory cytokines, such as IL-1 β , IL-6, and TNF [30]. This acute inflammatory response may be associated with increased risk of infection. Indeed, in a rat model, non-alcoholic hepatic steatosis was associated with higher mortality and liver injury after endotoxin administration [31]. Several groups have observed increased infectious complications and higher mortality rates during enteral and parenteral feeding with lipid in severely burned patients [6–8, 32]. Moreover, a retrospective study in burned children who did not survive the acute phase of their hospital stay showed that fatty metamorphosis of the liver was associated with sepsis [8, 33]. In the present study, the number of patients who did not survive was considerably small, and thus no significant difference in mortality rates between patients receiving a high-fat diet versus those receiving a low-fat/high-carbohydrate diet could be established. However, patients receiving Vivonex®T.E.N. lived significantly longer until death than those receiving milk.

Conclusions

We found that the time period when a high-fat diet was given had an increased incidence of fatty liver metamorphosis, organomegaly, and sepsis, shortened survival, and longer LOS in the ICU in pediatric burn patients compared to the time period when a low-fat/high-carbohydrate diet was given. Based on the findings of our study, we suggest that using a diet high in carbohydrate and low in fat rather than a diet high in fat and low in carbohydrate should be considered. However, before recommendations to change the standard of care can be made, a prospective randomized multicenter trial to determine the effect of nutrition on post burn outcomes should be conducted.

Acknowledgments

We thank all the individuals who participated in this clinical trial. We also would like to thank the research staff, especially Deb Benjamin for the assistance.

Sources of support: This study was supported by the American Surgical Association Foundation, Shriners Hospitals for Children 8660, 8640, 8760, and 9145, NIH R01-GM56687, T32 GM008256, and P50 GM60338, and NIDRR H133A020102.

REFERENCES

1. Wolfe RR, Herndon DN, Jahoor F, et al. Effect of severe burn injury on substrate cycling by glucose and fatty acids. *N Engl J Med.* 1987; 317:403. [PubMed: 3614284]
2. Herndon DN, Tompkins RG. Support of the metabolic response to burn injury. *Lancet.* 2004; 363:1895. [PubMed: 15183630]
3. Demling RH, Seigne P. Metabolic management of patients with severe burns. *World J Surg.* 2000; 24:673. [PubMed: 10773119]
4. Herndon DN, Hart DW, Wolf SE, et al. Reversal of catabolism by beta-blockade after severe burns. *N Engl J Med.* 2001; 345:1223. [PubMed: 11680441]
5. Saffle JR, Graves C. Nutritional support of the burned patient. In: Herndon, DN., editor. *Total Burn Care.* London: Saunders; 2007. p. 398
6. Garrel DR, Razi M, Lariviere F, et al. Improved clinical status and length of care with low-fat nutrition support in burn patients. *JPEN J Parenter Enteral Nutr.* 1995; 19:482. [PubMed: 8748363]
7. Mochizuki H, Trocki O, Dominioni L, et al. Optimal lipid content for enteral diets following thermal injury. *JPEN J Parenter Enteral Nutr.* 1984; 8:638. [PubMed: 6441004]
8. Barret JP, Jeschke MG, Herndon DN. Fatty infiltration of the liver in severely burned pediatric patients: autopsy findings and clinical implications. *J Trauma.* 2001; 51:736. [PubMed: 11586168]
9. Hart DW, Wolf SE, Zhang XJ, et al. Efficacy of a high-carbohydrate diet in catabolic illness. *Crit Care Med.* 2001; 29:1318. [PubMed: 11445678]
10. Gore DC, Rutan RL, Hildreth M, et al. Comparison of resting energy expenditures and caloric intake in children with severe burns. *J Burn Care Rehabil.* 1990; 11:400. [PubMed: 2246309]
11. Hildreth MA, Herndon DN, Desai MH, et al. Current treatment reduces calories required to maintain weight in pediatric patients with burns. *J Burn Care Rehabil.* 1990; 11:405. [PubMed: 2123202]
12. Hildreth MA, Herndon DN, Desai MH, et al. Caloric requirements of patients with burns under one year of age. *J Burn Care Rehabil.* 1993; 14:108. [PubMed: 8454656]
13. Hildreth MA, Herndon DN, Desai MH, et al. Reassessing caloric requirements in pediatric burn patients. *J Burn Care Rehabil.* 1988; 9:616. [PubMed: 3146576]
14. Hildreth MA, Herndon DN, Desai MH, et al. Caloric needs of adolescent patients with burns. *J Burn Care Rehabil.* 1989; 10:523. [PubMed: 2600100]
15. Hildreth MA, Herndon DN, Parks DH, et al. Evaluation of a caloric requirement formula in burned children treated with early excision. *J Trauma.* 1987; 27:188. [PubMed: 3546712]
16. Greenhalgh DG, Saffle JR, Holmes JH, et al. American Burn Association consensus conference to define sepsis and infection in burns. *J Burn Care Res.* 2007; 28:776. [PubMed: 17925660]
17. Hart DW, Wolf SE, Chinkes DL, et al. Determinants of skeletal muscle catabolism after severe burn. *Ann Surg.* 2000; 232:455. [PubMed: 10998644]
18. Hart DW, Wolf SE, Mlcak R, et al. Persistence of muscle catabolism after severe burn. *Surgery.* 2000; 128:312. [PubMed: 10923010]
19. Mlcak RP, Jeschke MG, Barrow RE, et al. The influence of age and gender on resting energy expenditure in severely burned children. *Ann Surg.* 2006; 244:121. [PubMed: 16794397]
20. Curreri PW, Richmond D, Marvin J, et al. Dietary requirements of patients with major burns. *J Am Diet Assoc.* 1974; 65:415. [PubMed: 4213656]
21. Ireton-Jones C, Jones JD. Improved equations for predicting energy expenditure in patients: the Ireton-Jones Equations. *Nutr Clin Pract.* 2002; 17:29. [PubMed: 16214963]
22. Allard JP, Pichard C, Hoshino E, et al. Validation of a new formula for calculating the energy requirements of burn patients. *JPEN J Parenter Enteral Nutr.* 1990; 14:115. [PubMed: 2112617]
23. Gottschlich MM, Jenkins M, Warden GD, et al. Differential effects of three enteral dietary regimens on selected outcome variables in burn patients. *JPEN J Parenter Enteral Nutr.* 1990; 14:225. [PubMed: 2112634]
24. Herndon DN, Nguyen TT, Wolfe RR, et al. Lipolysis in burned patients is stimulated by the beta 2-receptor for catecholamines. *Arch Surg.* 1994; 129:1301. [PubMed: 7986160]

25. Martini WZ, Irtun O, Chinkes DL, et al. Alteration of hepatic fatty acid metabolism after burn injury in pigs. *JPEN J Parenter Enteral Nutr.* 2001; 25:310. [PubMed: 11688934]
26. Aarsland A, Chinkes D, Wolfe RR, et al. Beta-blockade lowers peripheral lipolysis in burn patients receiving growth hormone. Rate of hepatic very low density lipoprotein triglyceride secretion remains unchanged. *Ann Surg.* 1996; 223:777. [PubMed: 8645051]
27. Pollack SV. Wound healing: a review III. Nutritional factors affecting wound healing. *J Dermatol Surg Oncol.* 1979; 5:615. [PubMed: 479447]
28. Wischmeyer PE, Lynch J, Liedel J, et al. Glutamine administration reduces Gramnegative bacteremia in severely burned patients: a prospective, randomized, double-blind trial versus isonitrogenous control. *Crit Care Med.* 2001; 29:2075. [PubMed: 11700398]
29. Mittendorfer B, Jeschke MG, Wolf SE, et al. Nutritional hepatic steatosis and mortality after burn injury in rats. *Clin Nutr.* 1998; 17:293. [PubMed: 10205353]
30. Jeschke MG, Low JF, Spies M, et al. Cell proliferation, apoptosis, NF-kappaB expression, enzyme, protein, and weight changes in livers of burned rats. *Am J Physiol Gastrointest Liver Physiol.* 2001; 280:G1314. [PubMed: 11352826]
31. Yang SQ, Lin HZ, Lane MD, et al. Obesity increases sensitivity to endotoxin liver injury: implications for the pathogenesis of steatohepatitis. *Proc Natl Acad Sci U S A.* 1997; 94:2557. [PubMed: 9122234]
32. Zaman N, Tam YK, Jewell LD, et al. Effects of intravenous lipid as a source of energy in parenteral nutrition associated hepatic dysfunction and lidocaine elimination: a study using isolated rat liver perfusion. *Biopharm Drug Dispos.* 1997; 18:803. [PubMed: 9429744]
33. Barrow RE, Mlcak R, Barrow LN, et al. Increased liver weights in severely burned children: comparison of ultrasound and autopsy measurements. *Burns.* 2004; 30:565. [PubMed: 15302422]

Figure 1.

Vivonex® T.E.N.-fed patients are associated with a shorter stay in the intensive care unit (A) and a decreased length of ICU Stay per % TBSA when compared to children receiving milk (B). Bars represent means; error bars correspond to SD. Asterisks denote statistical difference between groups, $p < 0.01$.

Figure 2.

Analysis of patients receiving Vivonex® T.E.N. revealed significantly lower incidence of sepsis (A) and a significantly longer survival rate (B, C) when compared to children receiving milk (20%). Bars represent means; error bars correspond to SD. Asterisks denote statistical difference between groups, $p < 0.01$.

Figure 3.

Vivonex®T.E.N.-fed burned children were associated with a significantly lower incidence of hepatic fatty metamorphosis (milk, $n = 57$, vs. Vivonex®T.E.N., $n = 78$) (A) and significantly lower spleen (milk, $n = 55$, vs. Vivonex®T.E.N., $n = 75$) (B) and kidney (milk, $n = 52$, vs. Vivonex®T.E.N., $n = 72$) (C) weights when compared to children receiving milk. Spleen and kidney weights, measured at autopsy, are presented as a percentage of predicted. Predicted weights are based on age and height. Bars represent means; error bars correspond to SD. Asterisks denote statistical difference between groups, $p < 0.05$.

Figure 4.

Annual rates of mortality (A), length of intensive care unit (ICU) stay (B) and incidence of sepsis (C) during the whole period studied. Bars represent means. Black errors indicate when the change in nutrition took place.

Table 1

Nutrition facts (panels) of formulations in this study

	Milk 300 ml	Vivonex®T.E.N. 300 ml
Calories	183 kcal	300 kcal
Protein	21%	15%
Carbohydrates	30%	82%
Fat	49%	3%
Glutamine	0	4.9 g/L
Protein	10 gm	11.5 gm
Carbohydrates	16 gm	61.7 gm
Fat	10 gm	0.8 gm

Each 2.84 oz dry packet reconstituted with 250 mL water, delivers 300 mL of formula (300 mL [1 packet]).

Table 2

Patient Demographics

Treatment groups	milk	Vivonex®T.E.N.	P-value
N	426	518	
Age (years)	7.1 ± 5.4	7.9 ± 5.2	0.08
Gender (F/M)	156/270	180/338	0.59
Burn to Admit (days)	8 ± 20	7 ± 13	0.82
TBSA (%)	61 ± 16	60 ± 21	0.21
3 rd Degree (%)	45 ± 27	44 ± 25	0.35
Mortality (%)	13	15	0.9

Data presented as means ± SD