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Nutrition in Burn Patients: Towards A New Caloric Ratio

M. S. Azzouzi[1]*, A. Hajjar[1], A. Zennour[1], O. Elatiqi[1], S. Boukind[1], M. D. Elamrani[1], Y. Benchamkha[1]

[1]Department of Plastic, Reconstructive and Burn Surgery, Mohammed VI University Hospital, Marrakech, Morocco

***Corresponding author:** M. S. Azzouzi
Department of Plastic, Reconstructive and Burn Surgery, Mohammed VI University Hospital, Marrakech, Morocco

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Abstract: Original Research

***Introduction*:** Nutrition in severely burned patients is an essential therapeutic pillar to combat hypercatabolism and prevent malnutrition. The objective of this study is to evaluate the clinical and biological efficacy of a systematic increase in calculated caloric needs by a factor of 1.5 in severely burned patients hospitalized at Mohammed VI University Hospital in Marrakech. ***Materials and Methods*:** Prospective analytical study in two phases (Phase 1: June 2018–December 2020; Phase 2: December 2020–2022), including 102 patients with total body surface area (TBSA) burned > 20%, admitted within 48 hours post-burn. Caloric needs were calculated according to Curreri (adults) and Schofield (children) formulas, multiplied by 1.5 during phase 2. A local enteral nutritional solution of 1,500 kcal/L was developed and introduced in phase 2. The primary endpoint is variation in body weight. Secondary endpoints are albumin level evolution and length of hospital stay. ***Results*:** Weight loss decreased from 8% (phase 1) to 3.5% (phase 2) ($p = 0.003$). Albumin level at discharge increased by 4 g/L compared to phase 1. Mean length of hospital stay decreased from 15 to 10 days ($p = 0.01$). A persistent intake deficit of 35 to 40% of calculated needs was observed, mainly related to digestive intolerances (45% of patients) and organizational constraints. ***Conclusion*:** Multiplication of calculated caloric needs by 1.5, combined with an adapted enteral nutritional solution, significantly improves clinical and biological parameters in severely burned patients. A multicenter randomized controlled trial is necessary to confirm these results.

Keywords: Severe Burns, Enteral Nutrition, Hypercatabolism, Caloric Ratio, Curreri Formula, Malnutrition.

1. INTRODUCTION

Severe burns represent a major organic injury whose pathophysiology is dominated by intense and prolonged hypermeta bolism and hypercatabolism [1, 2]. The systemic inflammatory response, associated with massive release of catecholamines, glucagon and cortisol, generates an increase in basal metabolism that can reach 200% of baseline value in the 7 to 20 days following the burn [2, 3]. This results in hyperglycemia, insulin resistance, lipid and protein hypercatabolism with muscle wasting and massive protein loss, exposing the patient to a high risk of severe malnutrition [4].

Nutrition thus constitutes an essential therapeutic pillar whose objectives are: to control and slow hypercatabolism, meet the increased basal metabolism, maintain lean body mass, promote metabolic control and support immune defenses [5, 6]. Early and appropriate nutritional support contributes directly to wound healing, reduction of infectious complications and decreased length of hospital stay [7, 8].

In resource-limited countries, implementation of optimal nutritional support faces significant economic, logistical and human constraints. To our knowledge, few studies from these contexts have evaluated the impact of systematic increase in calculated caloric intake on clinical and biological parameters in severely burned patients. Our work, conducted at Mohammed VI University Hospital in Marrakech over a four-year period, fits into this pragmatic and contextualized approach.

The study comprises two phases. **Phase 1** (June 2018–December 2020) constitutes an assessment of nutrition in severely burned patients in our facility, aimed at evaluating actual nutritional needs and intake and identifying obstacles to their optimization. **Phase 2** (December 2020–2022) pursues two objectives: to increase the energy target by 50% by multiplying calculated caloric needs by a factor of 1.5; and to create and administer a local enteral nutritional solution, adapted to the economic context of patients, then evaluate its efficacy.

2. Review of nutrition in severely burned patients

2.1. Pathophysiology of hypermetabolism

Burns exceeding 20% of total body surface area (TBSA) cause major anatomical, physiological, metabolic and immunological disturbances [9, 10]. The response to severe burns evolves in three distinct phases [11]:

- **Resuscitation phase (D0-D3):** hemodynamic instability related to fluid extravasation with systemic inflammatory response syndrome (SIRS)
- **Hypermetabolic phase (D4 until complete coverage):** intense hypermetabolism with increased metabolic fluxes
- **Rehabilitation phase:** period extending up to 12-24 months after the burn in the most severely burned patients

Intense and prolonged secretion of endogenous catecholamines constitutes the main mechanism of hypermetabolism [12, 13]. Added to this is the release of stress hormones (glucagon, cortisol) and inflammatory mediators (cytokines), creating a major catabolic state characterized by [14, 15]:

- An increase in basal metabolism of 118 to 210% of normal values
- A resting energy expenditure (REE) that can reach 200% without early excision, capping at 160% with early surgery
- Hyperglycemia and insulin resistance
- Protein hypercatabolism with muscle wasting (nitrogen losses 20-25 g/day)
- Intense lipolysis with mobilization of lipid reserves

2.2. Objectives of nutritional support

Nutritional support for severely burned patients aims to [16, 17]:

1. Meet the increased basal metabolism and increased demand for energy and nutrients
2. Control hypercatabolism and maintain lean body mass
3. Promote metabolic control (limitation of hyperglycemia, modulation of catecholamine impact)
4. Support immune defenses and reduce infectious risk
5. Facilitate surgery and promote wound healing
6. Prevent malnutrition and its complications (delayed wound healing, nosocomial infections, prolonged hospitalization)

2.3. Routes of administration and timing

Early enteral nutrition (EEN), initiated within 6 to 24 hours following the burn, is the preferred route of administration because it [18-20]:

- Preserves intestinal mucosal integrity
- Limits bacterial translocation
- Prevents stress ulcers
- Reduces the risk of acalculous cholecystitis
- Minimizes septic complications

Administration is initially via **nasogastric tube** (NGT) when oral feeding is impossible (sedated, intubated, non-cooperative, too weak patient). **Post-pyloric** positioning may be considered in case of gastroparesis or severe gastric intolerance [21].

Parenteral nutrition is reserved for situations where the enteral route is contraindicated (major electrocution, uncertain digestive integrity) or insufficient to cover needs (cumulative energy deficit > 8,000 kcal) [22].

2.4. Calculation of energy needs

Several formulas are used to estimate caloric needs in burned patients [23, 24]:

Table 1: Main formulas for calculating energy needs in burned patients

Formula	Equation
Curreri (adult)	(25 kcal × weight in kg) + (40 kcal × % TBSA)
Toronto	$-4343 + (10.5 \times \%TBSA) + (0.23 \times calintake) + (0.84 \times HB) + (114 \times T°C) - (4.5 \times dayspost - burn)$
Schofield (child)	BMR by age and sex × activity factor × stress factor

Indirect calorimetry, when available, remains the reference method for precisely determining resting energy expenditure [25]. In its absence, predictive formulas constitute an acceptable alternative, although sometimes tending to overestimate actual needs.

2.5. Macronutrient requirements

Macronutrient distribution should respect the following proportions [26, 27]:

- **Carbohydrates:** 60-65% of total energy intake (5-7 g/kg/d), main energy substrate
- **Lipids:** 15-20% of energy intake (1-1.5 g/kg/d), glucose sparing
- **Proteins:** 20-25% of energy intake (1.5-2.5 g/kg/d), up to 3 g/kg/d in the most severely burned patients to combat protein catabolism

Micronutrient intake (zinc, selenium, copper, vitamins C and E) should also be optimized to promote wound healing and support antioxidant defenses [28].

3. Materials and Methods

3.1. Study type and setting

This is a prospective comparative analytical study in two sequential phases, conducted in the burn intensive care unit of Mohammed VI University Hospital in Marrakech, from June 2018 to December 2022.

3.2. Study population

Inclusion criteria: Any patient hospitalized in the burn intensive care unit with total body surface area (TBSA) burned > 20%, admitted within 48 hours following the burn.

Exclusion criteria: Patients who died in the first 48 hours of hospitalization, patients with pre-existing chronic pathology likely to alter nutritional status (chronic renal failure, hepatic cirrhosis, active neoplasia), as well as pregnant or breastfeeding women were excluded.

Sample size calculation: Sample size was estimated based on an expected difference of 4% in percentage weight loss between the two phases (statistical power of 80%, risk $\alpha = 0.05$), requiring a minimum of 45 patients per group. The 102 patients included (approximately 51 per period) meet this requirement.

3.3. Data Collection

Epidemiological, clinical, paraclinical data and nutritional follow-up were collected for each patient using a standardized nutritional evaluation form. Parameters collected included: age, sex, weight at admission and discharge, BMI, TBSA, burn mechanism, feeding delay, prescribed and received caloric intake, albumin and blood protein levels at admission and discharge, presence of digestive intolerances, and length of hospital stay.

3.4. Nutritional protocol

Phase 1 (2018–2020): Nutritional needs were calculated according to European Society for Clinical Nutrition and Metabolism (ESPEN) recommendations, using the Curreri formula for adults and the Schofield formula for children. Nutrition was administered enterally orally or via nasogastric tube (NGT) in case of major digestive intolerance, and supplemented by parenteral nutrition if necessary. Patients received hospital meal trays providing 1,100 kcal, with or without oral supplementation (Promax® powder or Fortimel® solution).

Phase 2 (2020–2022): The energy target was increased by 50% by multiplying calculated needs (Curreri × 1.5 for adults; Schofield × 1.5 for children). An enteral nutritional solution was developed in the Errazi hospital kitchen, in collaboration with the department dietitian and chefs. This solution, containing 1,500 kcal per liter, was administered via NGT, divided over 24 hours, in addition to daily meals. Its macronutrient composition was defined to cover needs for carbohydrates (60–65% of caloric

intake), lipids (15–20%) and proteins (20–25%), in accordance with recommendations for severely burned patients.

3.5. Nutritional monitoring

Nutritional monitoring included: systematic weekly weighing, measurement of albumin and blood protein levels at admission and discharge. Other biological markers for nutritional monitoring (prealbumin/transthyretin, CRP, nitrogen balance) were not available in our center at the time of the study.

Digestive intolerance was defined on clinical criteria: abdominal pain, vomiting, bloating or transit disorders. It was managed symptomatically, according to its severity, by appropriate oral treatment.

3.6. Endpoints

- **Primary endpoint:** variation in percentage body weight between admission and discharge
- **Secondary endpoints:** evolution of serum albumin level between admission and discharge; mean length of hospital stay; rate of digestive intolerance

3.7. Statistical analysis

Quantitative data are expressed as mean ± standard deviation and qualitative data as numbers and percentages. Comparison of means between the two phases was performed by Student's t-test for normally distributed variables, and by Mann-Whitney test for non-Gaussian distribution. Comparison of proportions used the Chi-square test or Fisher's exact test according to sample sizes. The significance threshold is $p < 0.05$. Analyses were performed using SPSS® version 25.0 software.

3.8. Ethics

The study received approval from the Ethics Committee of Mohammed VI University Hospital in Marrakech (reference: CEth-CHU-MVI-2018-07). Written informed consent was obtained from each patient or their legal guardian for minor patients, in accordance with the principles of the Declaration of Helsinki.

4. RESULTS

4.1. Epidemiological Characteristics

A total of 102 patients were included: 49 in phase 1 and 53 in phase 2. Mean age is 29 years (range: 5–90 years). Male predominance is noted with 68% men versus 32% women. The two groups were comparable on admission characteristics (age, sex, TBSA, BMI) without statistically significant difference ($p > 0.05$ for all parameters).

Table 2: Epidemiological characteristics of the study population (n=102)

Parameter	Value
Mean age	29 years (5-90 years)
Male sex	68%
Female sex	32%
Mean TBSA	29%
Rural origin	Predominant
Adult mechanism	Butane flame
Child mechanism	Scalding

Overall mean length of hospital stay is ±14 days (range: 3 days–7 months).

4.2. Delay to initiation of nutrition

The majority of patients were admitted before H48 post-burn. Mean delay between burn occurrence and initiation of feeding is 29 hours (range: 6 hours to 1 day), partly explained by initial transit of patients through other departments (emergency, surgical intensive care) before admission to our unit.

Table 3: Interval between burn and initiation of feeding

Feeding delay	Number
< 12 hours	22%
12-24 hours	45%
24-48 hours	33%

4.3. Nutritional intake

Mean BMI at admission is 24.2 in adults and 19.45 in children. All patients received enteral nutrition: 88% orally and 12% via NGT.

Caloric needs calculated according to Curreri × 1.5 are **4,175 kcal/d** in adults and **1,800 kcal/d** in children (phase 2), versus 2,600 kcal/d and 1,200 kcal/d respectively in phase 1.

Table 4: Calculated caloric needs vs received intake (Phase 2)

Population	Calculated needs	Received intake
Adults (Phase 2)	4,175 kcal/d	2,714 kcal/d (65%)
Children (Phase 2)	1,800 kcal/d	1,260 kcal/d (70%)

Actual intake covers only **65% of calculated needs** in adults and **70%** in children ($p < 0.001$ for both groups). This deficit is attributable to lack of nursing staff for continuous administration, digestive intolerances, voluntary NGT removal by patients and interruptions related to paraclinical examinations.

4.4. Weight Evolution

Weight loss is observed in both phases. In phase 1, mean weight loss represents **8%** of initial weight. In phase 2, this percentage significantly decreased to **3.5%** ($p = 0.003$), with an overall mean loss of 4.5 kg between admission and discharge.

Table 5: Comparison of weight evolution between the two phases

Parameter	Phase 1	Phase 2	p-value
Weight loss (%)	8%	3.5%	0.003
Mean loss (kg)	6.2 kg	3.1 kg	0.005

4.5. Biological evolution

Serum albumin level in phase 1 was 30 g/L at admission and 28 g/L at discharge (difference: -2 g/L). In phase 2, albumin level at discharge increased by **4 g/L** compared to admission level, representing favorable evolution compared to phase 1.

Table 6: Evolution of serum albumin level

Phase	Albumin admission	Albumin discharge
Phase 1 (2018-2020)	30 g/L	28 g/L
Phase 2 (2020-2022)	30 g/L	34 g/L

It should be noted that this parameter is biased by systematic infusions of 20% albumin administered when the level was below 25 g/L, which limits its interpretation as an isolated marker of nutritional efficacy.

4.6. Length of hospital stay

Mean length of hospital stay decreased from **15 days** (phase 1) to **10 days** (phase 2) ($p = 0.01$), indirectly reflecting better wound healing and reduction in complications.

4.7. Digestive intolerances

In the overall series, **45% of patients** developed digestive intolerance, manifested mainly by abdominal bloating (68% of intolerances) and digestive pain (52% of intolerances). Symptom frequency increased in phase 2 compared to phase 1, probably related to higher intake. These intolerances were managed symptomatically (prokinetics, antispasmodics).

5. DISCUSSION

5.1. Pathophysiological context

Burns exceeding 20% of TBSA cause major anatomical, physiological and immunological disturbances whose extent depends on trauma severity and individual patient response [9, 10]. The resulting hypermetabolism can reach 200% of resting energy expenditure without early burn excision, and persist for several months [11, 13]. Early surgery attenuates these metabolic surges, capping energy expenditure at 160% in the most severely burned patients [14].

5.2. Nutritional support and coverage of needs

Current ESPEN recommendations emphasize the importance of nutritional support initiated early, preferably enterally, aimed at covering 80 to 120% of calculated needs [5, 6]. In our series, actual intake covers only 65 to 70% of calculated needs, a deficit similar to that reported in other series from resource-limited countries [4, 29]. This result emphasizes the need to improve nursing care organization for continuous administration and monitoring of enteral nutrition.

The Curreri formula used in our study is recognized for tending to overestimate actual needs compared to indirect calorimetry [30]. Nevertheless, in our context where indirect calorimetry is not available, application of a

multiplication factor of 1.5 represents a pragmatic and accessible approach, whose clinical results are encouraging.

5.3. Clinical and biological efficacy

Results from phase 2 show a significant reduction in weight loss (8% vs 3.5%, p = 0.003) and length of hospital stay (15 vs 10 days, p = 0.01), in agreement with literature data establishing that adequate nutritional intake promotes wound healing and reduces infectious complications [7, 8, 16]. Improvement in albumin level at discharge in phase 2 (+4 g/L vs -2 g/L in phase 1) is also an encouraging biological signal, although biased by exogenous albumin administration.

These results suggest that an aggressive nutritional strategy, adapted to local context and economically accessible, can significantly improve prognosis of severely burned patients hospitalized in intensive care.

5.4. Challenges and obstacles

Persistent intake deficit (35-40% of prescribed needs not received) constitutes a major obstacle to nutritional optimization. Identified causes are multiple: lack of nursing staff for continuous administration and monitoring, digestive intolerance (45% of patients), voluntary NGT removal by patients, interruptions related to paraclinical examinations. These obstacles require a comprehensive organizational approach including strengthening nursing staff, staff training, systematic preventive use of prokinetics and improvement of transit management protocols.

5.5. Study limitations

Our work has several methodological limitations that should be explicitly mentioned:

1. **Non-randomized design:** The two-phase sequential design without randomization or contemporary control group exposes to temporal bias. Parallel improvements in surgical, infectious disease or nursing care between 2018 and 2022 could contribute to observed benefits.
2. **Limited biological monitoring:** Biological monitoring restricted to albumin and blood proteins reduces sensitivity of nutritional evaluation. More sensitive markers (prealbumin/transthyretin, CRP, nitrogen balance, creatinine excretion) would be necessary for more rigorous analysis [31].
3. **Measurement bias:** Systematic administration of exogenous albumin when the level was below 25 g/L biases this parameter and limits its interpretation.
4. **Single-center study:** The single-center nature of the study and context specificity (limited resources, Morocco) limit generalizability of results to other facilities or countries.
5. **Absence of indirect calorimetry:** Inability to directly measure resting energy expenditure limits precision of actual need assessment.

These limitations justify future conduct of a multicenter randomized controlled trial to confirm our conclusions with a higher level of evidence.

5.6. Perspectives

Perspectives from this work include:

- Implementation of a multicenter randomized controlled trial comparing two nutritional strategies (calculated needs vs needs × 1.5).
- Integration of expanded biological monitoring (prealbumin, nitrogen balance, CRP, creatinine excretion).
- Evaluation of mortality at 28 days and 90 days as primary endpoint.
- Cost-effectiveness analysis of local nutritional solution.
- Implementation of digestive intolerance prevention protocols (systematic prokinetics, prone position > 30°).
- Improvement of care organization to reduce intake deficit.

6. CONCLUSION

Severe burns generate intense hypermetabolism and hypercatabolism, creating considerably increased nutritional needs that standard protocols struggle to meet in resource-limited facilities. Our study demonstrates that systematic multiplication of calculated caloric needs by a factor of 1.5, combined with administration of a low-cost local enteral nutritional solution (1,500 kcal/L), significantly

improves clinical parameters (reduction in weight loss from 8% to 3.5%, decrease in length of hospital stay from 15 to 10 days) and biological parameters (improvement in albumin level by +4 g/L) of severely burned patients hospitalized in intensive care.

This nutritional protocol adapted to the economic and organizational context of patients represents a practical and reproducible advance in our facility. Despite a persistent intake deficit of 35-40% related to organizational constraints and digestive intolerances, clinical benefits are significant and encourage continuation of this strategy.

Validation of this protocol by a multicenter randomized controlled trial, integrating expanded biological monitoring (prealbumin, nitrogen balance, CRP) and evaluation of mortality at 28 days, constitutes the priority perspective of this work to raise the level of evidence and allow its potential integration into clinical practice recommendations.

Conflicts of Interest: None declared

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