

**ENTERAL NUTRITION IN THE CRITICALLY ILL CHILD WITH SHOCK:  
PROSPECTIVE OBSERVATIONAL STUDY**

**Jesús López-Herce PhD MD, Santiago Mencía MD, César Sánchez PhD MD, Maria  
José Santiago MD, Amaya Bustinza MD, Dolores Vigil MD\***

Pediatric Intensive Care Unit

\* Preventive Service

Hospital General Universitario Gregorio Marañón

Madrid. Spain.

Correspondence: Jesús López-Herce Cid

Sección de Cuidados Intensivos Pediátricos

Hospital GU Gregorio Marañón

Dr Castelo 47

28009 Madrid

email: [pielvi@ya.com](mailto:pielvi@ya.com)

FAX: 34915868018

Telephone: 34915290327

## ABSTRACT

**Background:** Tolerance to enteral nutrition in the critically ill child with shock has not been studied. The purpose of the study was to analyze the efficacy and tolerance of enteral nutrition in the critically ill child with shock.

**Methods:** A prospective, observational study was performed including critically ill children with shock who received transpyloric enteral nutrition (TEN). The type of nutrition used, its duration, tolerance, and gastrointestinal complications were assessed. Children with shock who received TEN were compared with the rest of the critically ill children receiving TEN.

**Results:** Sixty-five critically ill children with shock aged between 21 days and 22 years, mean age  $37.6 \pm 54.4$  months, received TEN. 75.4% of patients received exclusively TEN. The mean duration of the TEN was  $25.2 \pm 42.2$  days and the maximum caloric intake was  $79.4 \pm 27.2$  kcal/kg/day. 20 patients with shock (30.7%) presented gastrointestinal complications, 10 (15.4%) abdominal distension and/or excessive gastric residue, 13 (20%) diarrhoea, 1 necrotising enterocolitis and 1 duodenal perforation due to the transpyloric tube. The frequency of gastrointestinal complications was significantly higher in children with shock than in the other critically ill children. TEN was suspended due to gastrointestinal complications in 6 patients with shock (9.2 %). 18 patients with shock and TEN (27.7%) died. In only one patient was the death related to complications of the nutrition.

**Conclusions:** Critically ill children with shock could tolerate transpyloric enteral nutrition, although the incidence of gastrointestinal complications is higher than in other critically ill children.

**Key words:** enteral nutrition, shock, critically ill children, diarrhoea, abdominal distension

## **BACKGROUND**

Enteral nutrition is effective and safe in the most of critically ill children (1,2). The early initiation of enteral nutrition may preserve mechanical and immunological gut barrier function, stimulating intestinal trophism, and reducing bacterial translocation and the incidence of sepsis and multisystem failure (3). It has few side effects. However, oral or nasogastric feeding is sometimes poorly tolerated in patients on mechanical ventilation, due to the reduced gastric motility secondary to the administration of drugs or to the disease itself, with the onset of distension, the accumulation of gastric residues, and a higher risk of pulmonary aspiration (4,5). For this reason, transpyloric enteral nutrition is used in the most severely ill patients, who have a lower tolerance to gastric nutrition, and/or with deep sedation and relaxation, in adults (6,7) and children (8-10). However, enteral nutrition is not generally administered in patients with shock. Enteral nutrition increases splanchnic metabolic demands, which may lead to oxygen and/or energy mismatch when the gut is hypoperfused (11). Shock reduces rapidly and severely the splanchnic perfusion altering the tolerance to enteral nutrition and can induce functional and structural gastrointestinal alterations and systemic complications (12). For this reason, critically ill patients who develop shock have been generally treated with parenteral nutrition. However, some studies have showed that patients after cardiac surgery with haemodynamic disturbances and/or requiring inotropic support tolerated adequately enteral nutrition (13,14). We have not found studies which have prospectively analysed the tolerance and adverse effects of enteral nutrition in children with shock. This has been the objective of the present study.

## **PATIENTS AND METHODS**

A prospective, observational study was performed which included all the critically ill children with shock admitted to the Paediatric Intensive Care Unit who received

transpyloric enteral nutrition (TEN). The study was approved by the Institutional Review Board. Shock was defined as a Blood Pressure  $< 2$  SD for normal level for age after more than 20 ml/kg of volume infusion and/or dopamine  $> 15$  mcg/kg/min and/or adrenaline  $> 0.3$  mcg/kg/min).

The TEN was used in children requiring mechanical ventilation, those with an altered conscious level and/or respiratory failure without mechanical ventilation and/or children with a risk of aspiration, and in those who did not tolerate gastric nutrition. The transpyloric tube was inserted by the nursing staff following a protocolised method, by blind insertion or with placement of the patient in a lateral decubitus position, with air insufflation (15). Confirmation of the position of the tube was initially performed by aspiration and measurement of the pH (it was considered that the tip of the tube was probably in the duodenum if the pH of the aspirate was equal to or higher than 6, and this was subsequently confirmed radiologically. All the tubes were situated between the 1<sup>st</sup> and 4<sup>th</sup> portions of the duodenum. A second tube was inserted via the same nasal orifice for drainage of the gastric contents and for measurement of the gastric residue every 3-4 hours.

The type of nutrition administered depended on the age of the patient: in children under 2-3 years, an infant formula was administered (700 kcal/L, x 18 g protein/L); this was substituted by protein hydrolysate in patients with milk-protein intolerance or a suspicion of intestinal damage. Calorie supplements in the form of dextrin-maltose, medium chain triglycerides or cereals were added in some patients. In children over 2-3 years of age, isocaloric (1.2 kcal/ml), normoproteic (26 g proteins/L) paediatric liquid formulae were administered. The alimentation was started at a rate of 0.5-1 ml/kg per hour, with increases of 0.5-1 ml/kg every 3-4 hours if the gastric residues were less than 25% of the volume

administered, until a calorie intake of 100 kcal per 100 kcal metabolised/day was achieved in the first 24 to 48 hours.

The following data were gathered prospectively: age, sex, weight, diagnosis, surgery, previous parenteral nutrition and its duration, indications for TEN, duration of admission before starting at TEN, maximum volume and calories administered, duration of the TEN, indications for withdrawal and subsequent type of nutrition. The doses of vasoactive drugs, sedatives and muscle relaxants administered during the TEN, the use of mechanical ventilation and its duration, altered liver function defined as an elevation of the AST to more than twice the normal value and/or of the bilirubin above 2 mg/dl, and nosocomial pneumonia after starting the TEN, defined according to the CDC criteria, were also recorded. Complications of enteral nutrition analysed were: significant abdominal distension, residues of the nutrition in the gastric aspirate with a volume greater than fifty percent of the volume administered in the previous four hours, diarrhoea and necrotising enterocolitis. Failure of the enteral nutrition was considered to have occurred when complications secondary to the nutrition developed that required its interruption.

The characteristics of the nutrition were compared between the patients with shock and the rest of the critically ill children who received TEN during the study period. The statistical analysis was performed using the SPSS version 12 statistical programme, expressing the quantitative variables as means and standard deviations, and the qualitative variables as percentages. Uni- or bivariate analyses were used to study statistical associations. The Chi-squared test was used for the analysis of the qualitative variables and Fisher's exact test for the quantitative variables when n was less than 20 or when any theoretical value was less than 5. Student's t test was used to compare quantitative variables between independent groups. Significance was taken as a  $p < 0.05$ .

## RESULTS

526 critically ill children received TEN, and 65 of them (12.3%) presented shock. Patients with shock has a mean age of 37.6 (54.4) months (range 21 days-22 years) and a weight of 14.6 (14.9) kg (range 2.8-70 kg). 33 children (50.8%) were under 1 year of age and 44 patients (67.6%) were male. The diagnoses of patients are summarised in Table 1. The indication for TEN was mechanical ventilation in 64 patients (98.5%), and intolerance to gastric nutrition in 1 (1.5%).

A comparison of the characteristics of the children with shock and the rest of the critically ill patients who received TEN is presented in Table 2. The children with shock had a significantly higher age and weight than the rest of the critically ill children who received TEN. A significantly higher percentage of patients with required dopamine, epinephrine and milrinone, and the dose of epinephrine and dopamine was also significantly higher in children with shock than in the rest of patients (Table 2). The percentage of patients with shock requiring continuous infusions of sedatives (midazolam and fentanyl) and muscle relaxants (vecuronium) was significantly higher than in the rest of critically ill children. The dose of midazolam and fentanyl was also significantly higher in children with shock. The children with shock presented a significantly higher incidence of acute renal failure (40 %) than the rest of children (5.9 %). The hepatic alteration in children with shock was also higher though the difference did not reach statistical significance. The mortality of patients with shock (27.7 %) was higher than in the rest of children (6.9%). (Table 2).

The characteristics of the nutrition are presented in Table 3. 21.5 % children with shock received parenteral nutrition previously to enteral nutrition. The frequency of children with had received parenteral nutrition prior to the TEN and the duration of parenteral nutrition were similar in patients with and without shock. In 67.6 % of patients with shock the TEN

was started within the first 2 days after admission in the PICU. There were non-significant differences in the time of starting the TEN and the percentage of patients in which the TEN was started in the first 48 hours after admission of the patient to the PICU, between children with shock and the rest of critically ill children.

The calorie intake received in the first day of TEN was lower in the children with shock (43.4 Kcal/kg/day) than in the rest of children (60.4 Kcal/kg/day) but the differences were not statistically significant. There are no differences in the maximum calorie intake achieved between the two groups. The duration of the TEN was significantly higher in the children with shock (25.2 days) than in the rest of children (12.7 days) (Table 3).

30 patients with shock (30.7%) presented gastrointestinal complications of TEN. The incidence of gastrointestinal complications in children with shock was significantly higher than in the rest of the critically ill children (Table 3). The incidence of abdominal distension and/or gastric residues (15.4%) and diarrhoea (20%) in the children with shock was significantly higher than in the remainder of the patients (5% and 4.6%). No relationship was found between the incidence of digestive tract complications and the age, weight, diagnoses, early or late administration of the TEN, the volume of nutrition or the quantity of calories administered. The definitive withdrawal of the nutrition was only necessary in 6 children (9.2%) due to digestive tract complications (duodenal perforation caused by the transpyloric tube, necrotising enterocolitis, gastrointestinal bleeding, diarrhoea, and abdominal distension). Death was related to mechanical complication of the nutrition (duodenal perforation) in one patient.

## **DISCUSSION**

Enteral nutrition is commonly contraindicated in shock due to the low mesenteric blood flow is a risk factor of bowel necrosis. In humans, feeding induce an increase in cardiac

output and vasodilation of mesenteric arteries, maintaining the balance between oxygen delivery and consumption. However, during shock splanchnic oxygen delivery is reduced while splanchnic oxygen consumption is maintained (14). In this situation, feeding can worsen the altered oxygen balance leading to gastrointestinal complications, and in rare occasions a small bowel necrosis can develop (16-18). However, Rokytka showed that in septic patients a low dose post-pyloric enteral nutrition led to a hyperemic systemic and hepato-splanchnic response with no altered energy balance or oxygen kinetics. The increase of total hepato-splanchnic blood flow was proportional to the increase of cardiac index (19). Similar effects were found by Revelly in cardiac patients (13).

However few studies evaluated the efficacy and safety of enteral nutrition in patients with hemodynamic alterations. Our study shows that children with shock can be fed by enteral nutrition although the incidence of complications is higher than other critically ill children. In our study, patients with shock had higher age and weight than the rest of critically ill children. However the age and weight has no relationship with the gastrointestinal complications.

The prevalence of acute mesenteric ischemia after cardiac surgery in adults varies between 0.5 and 1.4 %, with a mortality between 11% and 27 % (20,21). However, in a recent study, Berger found that enteral nutrition was well tolerated in adults with hemodynamic failure after cardiac surgery (14). In our study, 66% of patients had cardiogenic shock in the postoperative state of cardiac surgery. We did not find differences in the enteral nutrition tolerance between patients in the postoperative cardiac surgery and the rest of patients. Our results show that the tolerance of nutrition is independent of the type of shock. Patients on extracorporeal membrane oxygenation (ECMO) have also risk of splanchnic ischemia.

However, several studies have showed that enteral nutrition is well tolerated in children and adults on ECMO (22-24).

The frequency of digestive tract complications in children with shock was significantly higher than in the rest of critically ill children. Patients with shock present other risk factors that could impair enteral tolerance. First, they required the administration of high doses of vasoactive drugs. Epinephrine and high doses of dopamine can reduce intestinal perfusion and impair the tolerance to nutrition. However, if epinephrine and dopamine increase cardiac output could improve splanchnic perfusion. King et al in a retrospective study on 55 critically ill children who received inotropic drugs found that many patients tolerate well enteral nutrition (25). This fact is in accordance with our experience in critically ill children (26). Berger found that enteral nutrition was well tolerated in adults with hemodynamic failure after cardiac surgery (14). However, enteral nutrient delivery was significantly negatively related with the dose of dopamine and norepinephrine (14). Probably, the effect of vasoactive drugs will depend, in each patient, on the dose and the hemodynamic situation.

Moreover, children with shock had a higher incidence of renal and mortality than the rest of critically ill children. Critically ill patients with acute renal failure can tolerate enteral nutrition although the incidence of gastrointestinal complications is higher (27,28). Finally, bowel motility is reduced in critically ill patients (29), and sedatives and muscle relaxants high doses of reduced gastrointestinal motility and could impair enteral tolerance. Moreover, patients with shock received sedatives and muscle relaxant more frequently and in higher doses than the rest of critically ill children. In spite of, in our study most of children with shock presented an adequate tolerance to the transpyloric nutrition.

In the most of our patients shock did not delayed the beginning of enteral nutrition. Thus the percentage of previous parenteral nutrition and the initiation of the nutrition in children with shock was similar than in the rest of critically ill children. Berger found that enteral nutrition is possible in the first postoperative week after cardiac surgery in adults (14). However, in this study enteral nutrition resulted in insufficient energy delivery and adult patients required combination with parenteral nutrition (14). In our study, the energy delivery administered in the first day of nutrition in patients with shock was lesser than in the rest of children. However, there were no significant differences in the maximum calorie intake reached between the two groups, and a sufficient calorie intake was administered by the enteral nutrition. Enteral nutrition was significantly longer in children with shock, probably due to the more severity illness.

The incidence of abdominal distension, vomiting and gastric residues in our children was of 15 %. The frequency varies between 20% and 70% in critically ill adults receiving enteral nutrition (4,5). The presence of excessive residues and of abdominal distension it is due to the existence of gastrointestinal paresis with a slowing of intestinal transit. The higher doses of dopamine, sedatives and muscle relaxants in our children with shock can be responsible, in part, of this complication.

The incidence of diarrhoea was of 15%, similar than that found in the critically ill adults (4,5), but significantly higher than in the rest of critically ill children. Shock produces diarrhoea because it impair small bowell function and permeability. In spite of, the diarrhoea in our patients was generally mild and improved after modification of the diet. Transpyloric enteral nutrition achieved an adequate digestion and absorption of the nutrients in most of our children with shock

Definitive withdrawal of the TEN due to digestive tract complications was required in 6 patients, (9.2 % of the children with shock). In these patients enteral nutrition was substituted by parenteral nutrition. Only two severe gastrointestinal complications occurred in children with shock who received TEN. A patient suffered a duodenal perforation due the insertion of the transpyloric tube, and other infant presented necrotizing enterocolitis. Necrotizing enterocolitis is more frequent in neonates (30). Hemodynamic alterations and enteral nutrition are two of the most important mechanisms of necrotizing enterocolitis (31).

## **CONCLUSIONS**

We conclude that transpyloric enteral nutrition is a effective method of nutrition for the critically ill child with shock, although the incidence of digestive tract complications is higher than in other critically ill patients. For this reason, enteral nutrition must be used with caution in patients with shock. Physicians must carefully check the appearance of gastrointestinal complications (excessive rest, abdominal distension, bloody diarrhoea or dilated loops of bowel or intramural gas on the radiographic studies). If gastrointestinal complications appear and it not improve with reduction or modification or the diet, enteral nutrition must be suspended and substituted by parenteral nutrition.

**COMPETING INTEREST**

The authors declare that they have no competing interest

**AUTHOR'S CONTRIBUTION**

Jesús López-Herce: conceived the study, participated in the design, collection and analysis of data and draft the manuscript

Santiago Mencía, César Sánchez Maria José Santiago and Amaya Bustinza participated in the design, collection and analysis of data and draft the manuscript

Dolores Vigil participated in the design of the study and performed the statistical analysis

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**TABLE 1. DIAGNOSES OF PATIENTS WITH SHOCK**

<b>Diagnosis</b>	<b>Number and percentage of patients</b>
<b>Postoperative cardiac surgery</b>	43 (66.1%)
<b>Respiratory insufficiency</b>	8 (12.3%)
<b>Other medical diagnoses</b>	12 (18.4%)
<b>Other surgery</b>	2 (3%)
<b>Total</b>	65

**TABLE 2. COMPARISON OF CLINICAL CHARACTERISTICS BETWEEN THE CHILDREN WITH SHOCK AND THE REST OF THE CRITICALLY ILL PATIENTS WHO RECEIVED TRANSPYLORIC NUTRITION**

	<b>SHOCK</b>	<b>Rest of patients</b>	<b>p</b>
Number of patients	65	461	
Age (months) Mean (SD)	37.6 (54.4)	21 (38.8)	<b>.020</b>
Weight (kg) Mean (SD)	14.6 (14.9)	9.1 (10.9)	<b>.000</b>
Sex (male/female)	44/21 (2.1/1)	248/213 (1.1/1)	<b>.045</b>
Cardiac surgery	44 (67.7 %)	330 (71.6 %)	.559
Dopamine Mean (SD) mcg/kg/min	62 (95.4%) 11.1 (8)	307 (66.6 %) 5.2 (5.1)	<b>.000</b> <b>.000</b>
Epinephrine Mean (SD) mcg/kg/min	49 (75.4 %) 0.5 (0.7)	71 (15.4 %) 0.1(0.6)	<b>.000</b> <b>.001</b>
Milrinone Mean (SD) mcg/kg/min	45 (69.2 %) 0.6 (0.1)	206 (44.7 %) 0.5 (0.1)	<b>.000</b> .246
Acute renal failure	26 (40 %)	27 (5.9 %)	<b>.000</b>
Hepatic disturbances	3 (4.8 %)	6 (1.3 %)	.081
Nosocomial pneumonia	9 (15.5 %)	38 (8.9 %)	.152
Mortality	18 (27.7 %)	32 (6.9 %)	<b>.000</b>
Midazolam Mean (SD) mcg/kg/min	64 (98.5 %) 7.3 (3.4)	384 (83.3 %) 4.6 (3.8)	<b>.000</b> <b>.000</b>
Fentanyl Mean (SD) mcg/kg/h	64 (98.5 %) 7 (3)	366 (79.4 %) 4.3 (3.6)	<b>.000</b> <b>.000</b>
Vecuronium Mean (SD) mg/kg/h	51 (78.5 %) 0.1 (0.04)	179 (38.8 %) 0.1 (0.08)	<b>.000</b> .660

**TABLE 3. COMPARISON OF CHARACTERISTICS OF NUTRITION BETWEEN THE CHILDREN WITH SHOCK AND THE REST OF THE CRITICALLY ILL PATIENTS WHO RECEIVED TRANSPYLORIC NUTRITION**

	<b>SHOCK</b>	<b>Rest of patients</b>	<b>p</b>
Number of patients	65	461	
Parenteral nutrition	14 (21.5 %)	80 (17.4 %)	.391
Mean (SD) days	8.3 (10.2)	8.4 (7.7)	.956
Days before TEN	3 (4.4)	3.7 (6.4)	.431
Initiation of the TEN within the first 48 h after admission	44 (67.6 %)	284 (61.6 %)	.275
Calorie intake in the first 24 h of TEN (kcal/kg/day)	43.4 (15.5)	60.4 (84.7)	.373
Maximum calorie intake (kcal/kg/day)	79.4 (27.2)	84.8 (24.9)	.106
TEN duration (days)	25.2 (42.2)	12.7 (16.3)	<b>.020</b>
Gastrointestinal complications	20 (30.7 %)	42 (9.1 %)	<b>.000</b>
Abdominal distension / excessive gastric residues	10 (15.4 %)	23 (5 %)	<b>.004</b>
Diarrhoea	13 (20 %)	21 (4.6 %)	<b>.000</b>
Necrotising enterocolitis	1 (1.5 %)	2 (0.4 %)	.432
Duodenal perforation	1 (1.5 %)	0	-
Definitive suspension of TEN	6 (9.2%)	5 (1%)	<b>.000</b>