REVIEW ARTICLE

Protein/Energy Debt in Critically Ill Children in the Pediatric Intensive Care Unit: Acute Kidney Injury As a Major Risk Factor

Alice Sabatino, RD, Giuseppe Regolisti, MD, Umberto Maggiore, MD, PhD, and Enrico Fiaccadori, MD, PhD

Acute kidney injury (AKI) is common in pediatric intensive care unit (PICU) patients. In this clinical setting, the risk of protein-energy wasting is high because of the metabolic derangements of the uremic syndrome, the difficulties in nutrient needs estimation, and the possible negative effects of renal replacement therapy itself on nutrient balance. No specific guidelines on nutritional support in PICU patients with AKI are currently available. The present review is aimed at evaluating the role of AKI as a risk condition for inadequate protein/energy intake in these patients, on the basis of literature data on quantitative aspects of nutritional support in PICU. Current evidence suggests that a relevant protein/energy debt, a widely accepted concept in the literature on adult intensive care unit patients with its negative implications for patients' major outcomes, is also likely to develop in pediatric critically ill patients, and that AKI represents a key factor for its development.

Introduction

CRITICALLY ILL PATIENTS are frequently admitted to the intensive care unit (ICU) with poor nutrition; moreover, many pathogenetic factors linked to critical illness, such as catabolism, increased nutritional needs, and immobilization, can further worsen their nutritional status.[1-3]

In this clinical setting, malnutrition is associated with increased mortality, more frequent complications, longer ICU stay, and higher costs.[4] Thus, an adequate nutrient intake could play a key role in maintaining nutritional status during the acute and the recovery phase of critical illness.

However, nutritional support in the ICU is often well below protein and energy needs. In fact, several studies on critically ill patients have shown that underfeeding is a common problem in the ICU because most of these patients fail to achieve nutrition intake goals.[5-8] Very common causes are inadequate nutrient intake prescription and incorrect estimation of nutritional requirements because direct measurements of actual needs are not routinely performed.[9] Thus, especially in the first days of ICU stay, a progressive deficit of nutrients is likely to develop, leading to a sort of cumulative protein/energy debt that is hardly paid back during the hospital stay. At least in adult populations this energy debt is associated with negative outcomes,[10-16] whereas recent data suggest better survival rates and less complications when nutritional support is tailored to the actual patient needs.[17-20]

Malnutrition is also frequently observed among patients with acute kidney injury (AKI) in the ICU and portends a highly negative prognosis.[21] These patients are likely to develop major protein/energy debts in the ICU on the basis of specific risk factors (e.g., difficulties in reference body weight estimation/measurement due to fluid balance derangements and nutrient removal by renal replacement therapy [RRT]) (Fig. 1).[22]

Few data are currently available on this topic concerning pediatric ICU (PICU) patients. The present review is thus aimed at the following:

1. Summarizing current nutritional practices in the PICU with special regard to AKI patients,
2. Comparing nutritional practices between critically ill pediatric patients with and without AKI, and
3. Evaluating the relationship between nutritional support and patient outcome in this highly vulnerable population.

AKI in PICU Patients

Despite recent major diagnostic and therapeutic advances, AKI in pediatric critically ill patients still represents a major clinical problem. In fact, a wide range of prevalence (10-80%) has been reported depending on the different definitions applied and the clinical setting considered.[23-25] Moreover, a more than 9-fold increase in hospital- and

Department of Clinical and Experimental Medicine, Acute and Chronic Renal Failure Unit, Parma University Medical School, Parma, Italy

Financial Disclosure: See Acknowledgments on page XXX.

Address correspondence to Enrico Fiaccadori, MD, PhD, Department of Clinical and Experimental Medicine, Parma University Medical School, Via Gramsci 14-43126, Parma, Italy. E-mail: enrico.fiaccadori@unipr.it

1051-2276/$36.00
http://dx.doi.org/10.1053/j.jrn.2013.08.007

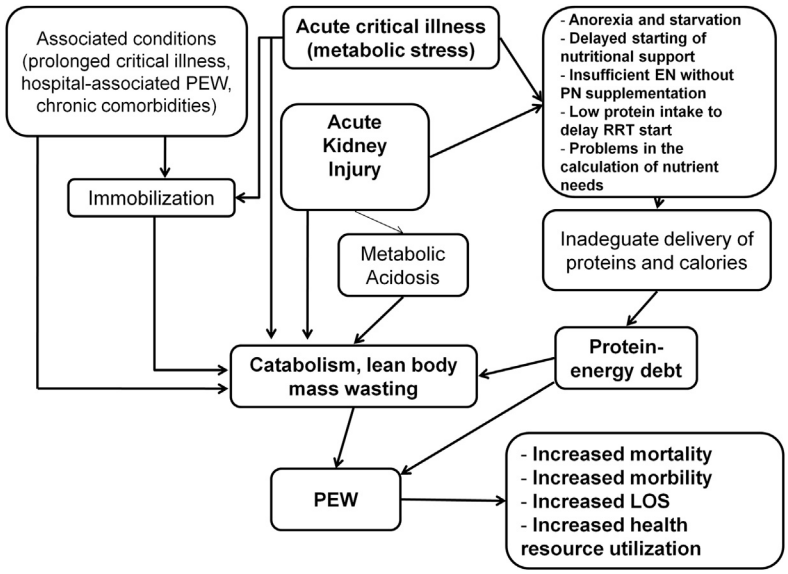

Figure 1. Pathogenesis of PEW in AKI. EN, enteral nutrition; LOS, length of stay; PEW, protein-energy wasting; PN, parenteral nutrition; RRT, renal replacement therapy.Reprinted with permission from Fiaccadori et al, *Curr Opin Clin Nutr Metab Care*. 2013;16:217-224.[22]

PICU-acquired AKI has been recently documented because of the increasing severity of illness of critically ill children and the more complex treatments and invasive procedures used.[26]

The different criteria for pediatric AKI definition and classification are illustrated in Table 1. The pediatric Risk, Injury, Failure, Loss, End-Stage Renal Disease score (pRIFLE)[24] is based on changes in the estimated creatinine clearance (eCCl), whereas the Acute Kidney Injury Network (AKIN) staging system[27] and the recently published Kidney Disease/Improving Global Outcomes (KDIGO) staging system and definitions[28] are based on changes in serum creatinine levels and/or urine output.

In the PICU clinical setting AKI more often develops early (usually in the first 2-5 days of stay). Although primary kidney diseases were the most common underlying conditions observed in the past, at present AKI is usually the consequence of a systemic illness or its treatment; in fact, an

Table 1. Diagnostic Criteria and Definitions of AKI in PICU Patients

AKI Definitions	sCr or eCCR Criteria	Urine Output Criteria
pRIFLE (2007)		
R	eCCl decrease by 25%	<0.5 mL/kg/h for 8 h
I	eCCl decrease by 50%	<0.5 mL/kg/h for 16 h
F	eCCl decrease by 75% or eCCl <35 mL/min/1.73 m^2	<0.5 mL/kg/h for 24 h or anuria for 24 h
Loss	Persistent failure >4 wk	
End-stage	Persistent failure>3 mo	
AKIN (2007)		
Stage 1	Increase in sCr of ≥0.3 mg/dL or increase to 150-200% from baseline	<0.5 mL/kg/h for >6 h
Stage 2	Increase in sCr to >200-300% from baseline	<0.5 mL/kg/h for >12 h
Stage 3	Increase in sCR to >300% from baseline or sCr ≥4 mg/dL, with an acute increase of ≥0.5 mg/dL	<0.3 mL/kg/h for 24 h or anuria for 12 h
KDIGO (2012)		
Stage 1	Increase in sCr by ≥0.3 mg/dL (≥26.5 μmol/L) within 48 h; or 1.5-1.9 times baseline, which is known or presumed to have occurred within the prior 7 d	<0.5 mL/kg/h for 6-12 h
Stage 2	sCR 2-2.9 times baseline	<0.5 mL/kg/h for ≥12 h
Stage 3	sCr 3 times baseline, or increase in sCr to ≥4 mg/dL (≥353.6 μmol/L), or initiation of RRT, or in patients <18 y of age decrease in eGFR to <35 mL/min/1.73 m^2	<0.3 mL/kg/h for ≥24 h or anuria for ≥12 h

AKI, acute kidney injury; AKIN, Acute Kidney Injury Network; eCCR, estimated creatinine clearance rate; eCCl, estimated creatinine clearance; eGFR, estimated glomerular filtration rate; KDIGO, Kidney Disease/Improving Global Outcomes; PICU, pediatric intensive care unit; pRIFLE, pediatric Risk, Injury, Failure, Loss, End-Stage Renal Disease score; RRT, renal replacement therapy; sCR, serum creatinine.