Very few pediatric studies have monitored nutritional status using normalized protein catabolic rate (nPCR) or treating protein-energy malnutrition (PEM) with intradialytic parenteral nutrition (IDPN). The current study compares nPCR with serum albumin as a marker for nutritional status and examines the effectiveness of IDPN treatment in three malnourished adolescent patients receiving chronic hemodialysis in a pediatric dialysis unit. All patients demonstrated reversal of weight loss and initiation of weight gain within 6 weeks of IDPN initiation. Mean values of monthly percentage weight and percentage body mass index (BMI) change were significantly lower in the pre-IDPN era (–0.61±2.70 and –1.3±2.7) versus the IDPN treatment period (1.8±2.1 and 1.3±2.1) (P<0.02). Two patients attained ideal body weight and IDPN was discontinued after 5 months. Patients required 150% recommended daily allowance to achieve weight and BMI gain. While mean monthly nPCR was significantly lower in the pre-IDPN period versus the IDPN period (1.05±0.36 versus 1.35±0.37, P<0.05), monthly serum albumin levels were no different before and after IDPN was initiated (3.7±0.8 versus 3.8±0.6). The current study demonstrates IDPN to be effective therapy for adolescent hemodialysis patients with PEM not correctable by enteral supplementation. nPCR was superior to serum albumin as a nutritional status marker in these malnourished pediatric patients receiving hemodialysis.

Keywords
Intradialytic parenteral nutrition · Malnutrition · Normalized protein catabolic rate · Hemodialysis

Introduction

Patients receiving chronic hemodialysis who exhibit protein-energy malnutrition (PEM) may be at risk for increased morbidity and mortality. Multiple studies assessing the impact of nutritional status upon mortality have concluded that PEM is an independent risk factor for death in adult patients receiving hemodialysis [1, 2, 3, 4, 5, 6]. Pediatric patients receiving hemodialysis do not exhibit high mortality rates, but PEM likely impairs growth and development in the children with end-stage renal disease (ESRD) [7].

The important relationship between nutritional status and outcome for patients with ESRD prompted the National Kidney Foundation Kidney-Dialysis Outcomes Quality Initiative (NKF-KDOQI) to create guidelines to assess and treat PEM in both children and adults with ESRD [7]. The pediatric K-DOQI guidelines recommend serum albumin, height/length, dry weight, mid-arm circumference, skinfold thickness, fronto-occipital circumference, and height Z-score to monitor nutritional status and intensive enteral nutrition to treat PEM. While these measures are essential to monitor and treat PEM, they may not be sufficient in all cases.

Intradialytic parenteral nutrition (IDPN) provides significant amounts of protein and calories to a patient during the hemodialysis treatment. IDPN is effective treatment for adult patients with PEM [8, 9, 10], and adult K-DOQI nutritional guidelines provide recommendations for IDPN use in adults. IDPN therapy has not been extensively studied in malnourished pediatric patients receiving hemodialysis [11, 12, 13] and pediatric K-DOQI nutritional guidelines do not address IDPN therapy.
Many adult outcome studies use normalized protein catabolic rate (nPCR) as an independent marker of nutritional status [14, 15, 16, 17]. nPCR is derived from the interdialytic rise in blood urea nitrogen levels and has been shown to correlate with nutritional status in adult patients receiving hemodialysis. No published pediatric study has used nPCR as a marker of nutritional status. In fact, little investigation into the validity of nPCR has been performed since the rigorous work of Grupe et al. [18] and Harmon et al. [19] 20 years ago, whose seminal studies in children receiving hemodialysis demonstrated a positive correlation between dietary protein intake and nPCR. They were the first to suggest that positive nitrogen balance, which is essential for growth, could be achieved with moderate protein intake and without an increase in dialysis requirements.

In our pediatric dialysis unit over the past 18 months, we have treated three severely malnourished adolescent patients with IDPN. We have routinely determined monthly nPCR values for the last 4 years in all of our pediatric hemodialysis patients. The aims of the current study are to investigate the effectiveness of IDPN for treating PEM and to compare the sensitivity of serum albumin versus nPCR for monitoring nutritional status in malnourished pediatric patients receiving hemodialysis.

### Materials and methods

**Patient population**

Three patients received IDPN for treatment of PEM during January 1999 through May 2001 in the Texas Children’s Hospital Renal Dialysis Unit. The lowest weight for each patient ranged from 35.9 to 45 kg. Patient ages were 17, 18, and 25 years and their height ages were 14 years 1 month, 11 years 4 months, and 11 years 11 months, respectively. All patients had completed their growth and demonstrated Tanner stage V sexual maturation.

To qualify for IDPN by our unit protocol, patients had to exhibit a ≥10% weight loss over a 3-month time span and have a gastrointestinal illness that precluded administration of sufficient enteral calories to achieve anabolism. The gastrointestinal causes of PEM in these patients were (1) chronic recurrent pancreatitis and malabsorption, (2) acute pancreatitis with an infected pancreatic pseudocyst and colonic perforation, and (3) severe gastritis, duodenal stricture, and abdominal wall abscess.

**IDPN prescription**

IDPN is comprised of three components: dextrose, amino acids, and lipids. The dextrose component was delivered as a 70% solution to provide 5-9 mg/kg per min of carbohydrate. The purpose of the IDPN carbohydrate component is to prevent catabolism and maximize utilization of the IDPN protein component. Serum glucose levels were monitored at the beginning, in the middle of, and immediately after IDPN administration during the 1st week of IDPN treatment or after any change in the dextrose rate. Patients with serum glucose levels >300 mg/dl received regular insulin in the IDPN preparation bag to maintain serum glucose <200 mg/dl.

The amino acid component (Novamine) was delivered as a 15% solution to provide 1.3 g/kg per treatment of protein [20]. The amino acid component was prepared and combined with the carbohydrate component in our outpatient pharmacy on the day of administration.

The lipid component of IDPN was provided as a 20% solution and delivered via a separate bottle. The lipid component is egg based, and is withheld from patients with a history of egg allergy. Patient serum triglyceride levels were checked before and after the first IDPN treatment. A 50% rise above baseline levels after lipid administration was indicative of lipid intolerance and resulted in discontinuation of future lipid administration for a particular patient.

The prescribed volume of IDPN was infused continuously over the entire course of the hemodialysis treatment. To minimize dialyzer clearance of amino acids, IDPN was administered via the venous limb of the hemodialysis circuit (i.e., post dialyzer). The total fluid volume of IDPN was based on the volume needed to deliver the carbohydrate and protein doses described above. The total volume associated with IDPN administration was removed via ultrafiltration over the course of the hemodialysis treatment.

**Nutritional status monitoring**

Mid-week monthly nutritional laboratory assessment included serum albumin and nPCR levels. Single-pool Kt/V and nPCR were calculated by single-pool urea kinetic modeling [21]. Post-dialysis patient weight and body mass index (BMI=wt(kg)/ht2 (m)) were obtained on the date of serum albumin and nPCR assessment. Month-to-month percentage of weight change and BMI change were used as outcome measures for IDPN therapy. In order to minimize the potential for observed weight gain to be the result of fluid accumulation and not true weight gain, all patients received ultrafiltration guided by non-invasive monitoring of hematocrit (Cris-line, Hemametrics, Salt Lake City, Utah, USA) during each dialysis session. We have previously demonstrated this to be effective in achievement of patient target dry weight with minimal patient symptomatology [22, 23].

**Statistical analysis**

To standardize assessment between the three patients, monthly data from the 4 months immediately prior to IDPN treatment were compared with data from the first 5 months of IDPN treatment. Mean values for serum albumin, nPCR, percentage weight change, percentage BMI change, and spKt/V from the pre-IDPN months and the IDPN months were compared using the paired t-test. A P value <0.05 was considered significant.

### Results

The three adolescent patients reported in this study were the only patients in our unit who exhibited severe PEM (≥20% weight loss over a 3-month time span) that could not be adequately treated with enteral supplementation alone. One patient received dialysis via an arteriovenous graft, one via an arteriovenous fistula, and one patient received dialysis via an indwelling catheter. None of the infants and children within our unit suffered from a significant gastrointestinal disorder that precluded successful enteral supplementation.

All three patients tolerated IDPN administration without adverse events. Total IDPN volume ranged from 478 ml to 597 ml depending on patient weight. One patient demonstrated lipid intolerance (50% increase in triglyceride level above baseline) and did not receive lipids after his first dose of IDPN. Another patient with acute pancreatitis developed transient insulin-dependent diabetes mellitus and required 6 units of regular insulin added to the IDPN preparation to keep serum glucose levels be-