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# Pilot validation of objective malnutrition—inflammation scores in pediatric and adolescent cohort on chronic maintenance dialysis

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**Abstract**

**Background:** In recognition of the challenges inherent with the use of single-item indices for the diagnosis of malnutrition–inflammation morbidity in pediatric dialysis patients, to enhance accuracy, we validated a composite scoring system in a pilot study. The objective malnutrition—inflammation score seeks to validate the use of a composite scoring system as a tool for assessing malnutrition—inflammation burden in a pediatric dialysis population.

**Methods:** We enrolled 20 patients on hemodialysis (n = 14) and peritoneal dialysis (n = 6) over a period of 12 months. We derived composite scores from selected indices of renal pathology, nutrition, dialysis adequacy, protein catabolism, and dialysis modality. We assessed reliability by a test–retest method and measured validity by defining the relationship of the indices with serum C-reactive protein in a multiple regression analysis. We calculated sensitivity, specificity, accuracy, and precision for the malnutrition—inflammation score.

**Results:** The mean age was 12.8 years (standard deviation = 6.1), and male–female ratio was 12:8. Patients (n = 8) with elevated serum C-reactive protein (>0.3 mg/dL) had higher composite score for malnutrition—inflammation morbidity. Similarly, the pediatric cohort on hemodialysis had higher score than those on peritoneal dialysis. Upon reliability testing, a low value of typical error (0.07) and high correlation coefficient (r = 0.95) supported validity of the instrument. Moreover, multiple regression analysis showed a strong predictive relationship ($R^2 = 0.9$, $p = 0.03$) between the indices and serum C-reactive protein. Sensitivity of malnutrition—inflammation score was 62.5%, specificity was 83%, accuracy was 75%, and precision was 71%.

**Conclusion:** Using criterion-validation method, we established the potential use of multi-diagnostic approach to quantify malnutrition—inflammation morbidity in a pediatric dialysis cohort. Given the small sample size, large-scale population-specific studies are needed to ratify these findings and to demonstrate its clinical effectiveness.

**Keywords**

Malnutrion-inflammation score, chronic hemodialysis, chronic peritoneal dialysis

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## Introduction

Protein energy wasting which manifests as progressive decline in body protein and fat masses is a universal occurrence in children with end-stage kidney disease (ESKD). It has been demonstrated to increase the risk of hospitalization and death in adults and children with chronic kidney disease.[1,2] While its early manifestation may be subtle, diagnosis of the late phases is often confounded by proximate events.[3] In addition, anthropometric indices are poorly reliable because of inter-observer errors and alteration in fluid status. Similarly, there are shortcomings with biochemical indices: serum transferrin is influenced by iron deficiency, and hypoalbuminemia may reflect plasma volume expansion.[4] Moreover, accuracy of serum albumin is confounded

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by losses during dialysis and cytokine inhibition of hepatic synthesis.[5]

Furthermore, clinical tools such as dietary recall, calorie count, and bio-electrical impedance analysis are time-consuming, operator-dependent, and resource intensive. In addition, given the complexity of nutritional adaptation in kidney disease, multidimensional diagnostic approach may be more appropriate. For these reasons, National Kidney Foundation/Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) recommends the use of multiple parameters at frequent intervals for nutritional evaluation in chronic dialysis patients.[6]

In the adult population, composite scoring system (Subjective Global Assessment) has been validated as a credible tool.[7] Its measurement predicts greater cardiovascular morbidity, higher mortality rate, and a lower quality-of-life index.[8–10] However, despite the greater uremic burden in children with kidney disease, similar tools are not widely available for pediatric use. In order to redress this imbalance, we selected the common indices of malnutrition and inflammation for composite scoring in a pediatric dialysis cohort.

## Patients and method

We enrolled all the 20 patients who were on dialysis for >3 months between the month of January and December 2012 at the Children's Hospital of New Orleans. Informed consent was obtained from the parents or legal guardians of all minors (age less than 18 years) prior to enrollment into the study. In addition, assents were also obtained in children older than 7 years of age. None of the patients met the exclusion criteria of rapid changes in clinical status and/or wide variation in laboratory values (e.g. severe sepsis) for at least 3 months before data collection. Data analysis was performed at the sixth month using the monthly laboratory studies performed as guided by the recommendation of NKF-KDOQI for chronic dialysis. The study protocol was approved by the LouisianaStateUniversityHealthSciencesCenter and Children's Hospital of New Orleans Institutional Review Boards.

We selected diagnostic indices for scoring on the basis of theoretical plausibility and literature proof of causative relationship with malnutrition—inflammation morbidity (MIM). These included primary renal pathology, body mass index (BMI), total iron binding capacity (TIBC), serum ferritin, serum albumin, serum cholesterol, normalized protein catabolic rate (nPCR), Kt/V, serum alkaline phosphatase, and dialysis modality.[11] In peritoneal dialysis (PD) patients, weights and heights were measured on clinic visits (weights included their Last fills). In hemodialysis (HD) patients, heights were obtained pre-dialysis and weights were obtained pre- and post-dialysis. For the purpose of BMI calculation, only post-dialysis weights were used. In HD patients, dialysis adequacy and nPCR were calculated using the Daugirdas formula, while in PD patients, adequacy and nPCR were calculated using the Baxter computer prescription program, PD ADEQUEST. All HD patients were on maintenance intravenous iron. PD patients received intravenous iron only when their serum iron levels and TIBC were low. We did not include residual renal function for scoring because of the small number of patients involved. Two composite units of 9- and 12-item objective malnutrition—inflammation score (OMIS) I and II, respectively, were created (Table 2). To determine reliability, scoring of the same set of indices was performed at 1-month interval by the same investigator (Franca Iorember, MD). All biochemical analyses were processed at the local laboratory services of Children's Hospital of New Orleans.

## Statistics

We assessed all data for normal distribution prior to statistical analysis. Descriptive analysis was performed. Nominal and ordinal data were expressed as frequencies while interval (or ratio) data were summarized as mean, percentiles, standard deviation (SD) (or 95% confidence intervals). Height and body mass indices were expressed as SD scores. To give equal weight to the measurements of adequacy for HD and PD, the respective Kt/V was graded by using the same scale to derive uniform scoring units prior to analysis (see Scoring indices of objective MIM below). In view of the small sample frame, we used Mann–Whitney U statistics to examine for equality of distribution of the clinical characteristics. The U values were reported at given 95% confidence limits. When appropriate, non-parametric data were normalized by a log transformation procedure prior to analysis (Microsoft Excel 2010). We assessed the tool for validity, a measure of diagnostic accuracy, by using the following three techniques:

1. Test–retest method: We examined two datasets of MIM score obtained at 1-month interval for change in the mean values, random variation (or typical error), and intra-class correlation coefficient.
2. Multiple regression analysis: Using serum C-reactive protein (CRP) as outcome variable, we performed regression analysis on the respective indices of OMIS I and OMIS II.[12,13] Because of its stronger predictive model, we adopted OMIS II for subsequent analysis.
3. We calculated sensitivity, specificity, accuracy, and precision for OMIS II. For all analyses, we accepted a p-value < 5% as the limit for the rejection of null hypothesis.

### *Scoring indices of objective MIM*

The component indices were scored as follows:

1. Primary renal pathology: non-inflammatory (e.g. dysplasia) = 0; somewhat inflammatory (e.g. focal segmental glomerulosclerosis) = 2; inflammatory (e.g. lupus nephritis) = 3

**Table 1.** Demographic characteristics of pediatric cohort on chronic peritoneal dialysis (PD) and hemodialysis (HD).

| Demographic data | HD | PD | All patients |
|---|---|---|---|
| Number of patients | 14 | 6 | 20 |
| Male:female ratio | 9:5 | 3:3 | 12:8 |
| Mean age (years) | 12.4 ± 6.3 | 13.6 ± 5.9 | 12.8 ± 6.1 |
| Mean weight (kg) | 40.3 ± 20.5 | 43.8 ± 26.5 | 41.4 ± 21.8 |
| Mean height (cm) | 134.7 ± 32.5 | 139.1 ± 40 | 136.1 ± 33.9 |
| Mean height SDS | 0.16 ± 0.73 | 0.27 ± 1.36 | 0.01 ± 0.90 |
| Mean BMI (kg/m$^2$) | 20.5 ± 4.3 | 21 ± 5.3 | 20.5 ± 4.5 |
| Mean BMI SDS | −0.01 ± 0.88 | 0.02 ± 1.2 | 0.001 ± 0.98 |

SDS: standard deviation score; BMI: body mass index.

**Table 2.** OMIS I and OMIS II items.

| | OMIS I | OMIS II |
|---|---|---|
| Clinical parameters | Disease pathology | Disease pathology |
| | Infection | Infection |
| | Dialysis modality | Dialysis modality |
| | Dialysis duration | Dialysis duration |
| | BMI | BMI |
| | Albumin | Albumin |
| | TIBC | TIBC |
| | Ferritin | Ferritin |
| | Kt/V | Kt/V |
| | | nPCR |
| | | Cholesterol |
| | | Alkaline phosphate |

OMIS I: 9-item objective malnutrition—inflammation score; OMIS II: 12-item objective malnutrition—inflammation score; BMI: body mass index; TIBC: total iron binding capacity; nPCR: normalized protein catabolic rate.

2. Serum albumin: >4 g/dL = 0; 3.5–3.9 g/dL = 1; 3.0–3.4 g/dL = 2; <3.0 g/dL = 3
3. Serum total iron binding capacity: >250 mg/dL = 0; 200–249 mg/dL = 1; 150–199 mg/dL = 2; <150 mg/dL = 3
4. BMI SD score: <−0.05 = 0; −0.04 to 1.5 = 1; −1.6 to 2.5 = 2; >−2.5 = 3
5. Dialysis duration: 0–1 year = 0; 1–3 years = 1; 3–5 years = 2; >5 years = 3
6. Serum cholesterol: >200 mg/dL = 0; 151–199 mg/dL = 1; 129–150 mg/dL = 2; <130 mg/dL = 3
7. nPCR: >1.2 = 0; 0.8–1.0 = 1.0; 0.7–0.79 = 2; <0.70 = 3
8. Serum alkaline phosphatase: >1000 mg/dL = 0; 750–1000 mg/dL = 1; 250–749 mg/dL = 2; <250 mg/dL = 3
9. Grade of infection: no infection = 0; 0.5× (number of low grade infection events, for example, line induced bacteremia, upper respiratory tract infection); 1.0× (number of moderate grade events, for example, symptomatic line sepsis, pneumonia), 1.5× (number of severe infection, for example, infection warranting hospitalization)
10. Dialysis modality: HD = 1; PD = 0
11. Dialysis adequacy: Kt/V (HD)—> 1.2 = 0; 1.0–1.19 = 1; 0.75–0.9 = 2; <0.75 = 3; Kt/V (PD)—weekly Kt/V > 2.2 = 0; 1.8–2.0 = 1; 1.5–1.79 = 2; <1.5 = 3
12. Serum ferritin: 0–500 mg/dL = 0; 501–750 mg/dL = 1; 751–1000 mg/dL = 2; >1001 mg/dL = 3

## Results

There were a total of 20 patients with 14 patients on HD and 6 patients on PD. The mean age of the study subjects was 12.8 years (SD = 6.1 years), with a range of 2–20 years. Patients on HD were younger with a mean age of 12.4 years (see Table 1). In all, 60% of the patients were male. There were 12 African Americans, 7 Whites, and 1 Hispanic. The mean weight was 41.4 kg (SD = 21.8 kg), mean height SD score (SDS) was 0.01 ± 0.90, and mean BMI SDS was 0.001 ± 0.98. Three dialysis patients (15%) had allograft failure (underlying diagnosis were hemolytic uremic syndrome, obstructive uropathy, and unknown in the third patient) and three had obstructive uropathy (15%) as the pre-dialysis renal disease. Two patients (10%) each had focal segmental glomerulosclerosis, lupus nephritis, and polycystic kidney disease. One of the lupus nephritis patients was receiving small dose prednisone at the time. There was one patient (5%) each who had interstitial nephropathy, Alport nephritis, membranoproliferative glomerulonephritis, acute kidney injury, and membranous nephropathy. Seven of the patients (50%) on HD had native arterio-venous fistula as vascular access, while the other half used double-lumen permanent catheters. HD frequency was 3 days a week.

Patients on HD had higher serum levels of ferritin, serum albumin, infection rates, and longer dialysis vintage but lower levels of TIBC and nPCR (Table 3). This suggested greater MIM in HD patients. In all, 12 patients had normal serum CRP (<0.3 mg/dL), while 8 patients had elevated values, ranging from 0.4 to 11.1 mg/dL (mean = 4.7 ± 4.7). Individuals with elevated serum CRP had statistically significant lower values of serum TIBC, serum albumin, nPCR, and greater frequency (and severity) of infection (Table 4). Test–retest reliability analysis showed that the changes in the mean value of log transformed dataset at 1-month interval

**Table 3.** Comparative analysis of clinical items used for the scoring of malnutrition—inflammation morbidity among subjects on hemodialysis (HD) and peritoneal dialysis (PD).

| Clinical parameters[a] | Raw data ± 95% confidence limits (CLs) | | Mann–Whitney | |
|---|---|---|---|---|
| | HD (n = 14) | PD (n = 6) | $U_A$ (95% CL = 17–67) | $P_I$ |
| Serum ferritin (mg/dL) | 1141 (851–1438) | 566 (120–1002) | 8 | 0.003 |
| Serum total iron binding capacity (mg/dL) | 194 (172–216) | 250 (175–325) | 70 | 0.040 |
| Serum cholesterol (mg/dL) | 154 (141–167) | 171 (138–204) | 44 | 0.450 |
| Serum albumin (g/dL) | 3.50 (3.2–3.8) | 2.80 (2.0–3.6) | 04 | 0.001 |
| Normalized protein catabolic rate (nPCR) | 0.90 (0.6–1.2) | 1.40 (0.4–2.4) | 68 | 0.056 |
| Serum alkaline phosphatase (mg/dL) | 461 (277–695) | 184 (69–299) | 68 | 0.056 |
| Dialysis adequacy (Kt/V) | 1.50 (1.3–1.6) | 2.0 (1.5–2.5) | 85 | 0.001 |
| Dialysis duration (months) | 33.0 (20–46) | 21.0 (10–32) | 46 | 0.380 |
| Frequency and severity of Infection score | 0.32 (0.1–0.7) | 0.16 (−0.2 to 0.5) | 48 | 0.360 |

nPCR: normalized protein catabolic rate.
[a]Lower values of total iron binding capacity, serum cholesterol, serum albumin, nPCR, serum alkaline phosphatase, and Kt/V are indicative of greater malnutrition—inflammation burden.

**Table 4.** Comparative analysis of scoring for malnutrition—inflammation morbidity among subjects on hemodialysis (HD) and peritoneal dialysis (PD).

| Scoring indices[a] | Scores ± 95% confidence limits | | Mann–Whitney | |
|---|---|---|---|---|
| | HD (95% CI); n = 14 | PD (95% CI); n = 6 | $U_A$ (95% CI = 17–67) | $P_I$ |
| Serum ferritin (mg/dL) | 2.8 (2.2–3.2) | 0.8 (−0.6 to 2.2) | 12 | 0.008 |
| Serum total iron binding capacity (mg/dL) | 1.6 (1.2–2.0) | 0.8 (−0.2 to 1.8) | 16 | 0.03 |
| Serum cholesterol (mg/dL) | 1.7 (1.2–2.2) | 1.2 (−0.2 to 2.2) | 36 | 0.32 |
| Serum albumin (g/dL) | 1.3 (0.8–1.8) | 2.5 (1.7–3.3) | 72 | 0.03 |
| Normalized protein catabolic rate (nPCR) | 2.1 (−1.5 to 2.7) | 1.0 (−0.3 to 2.3) | 16 | 0.03 |
| Serum alkaline phosphatase (mg/dL) | 1.8 (−1.2 to 2.4) | 2.7 (2.2–3.2) | 67 | 0.055 |
| Dialysis adequacy (Kt/V) | 0.2 (−0.03 to 0.4) | 0.3 (−0.5 to 1.2) | 46 | 0.38 |
| Dialysis duration (months) | 1.3 (0.7–1.9) | 1.0 (−0.4 to 1.6) | 27 | 0.30 |
| Frequency and severity of Infection score | 0.4 (−0.1 to 0.9) | 0.2 (−2.4 to 0.5) | 36 | 0.32 |
| Objective malnutrition—inflammation score I | 9.2 (8.2–10.6) | 8 (4.6–11.4) | 26 | 0.30 |
| Objective malnutrition—inflammation score II | 15.0 (13–17) | 12.5 (8–18) | 60 | 0.11 |

CI: confidence interval.
U: Mann–Whitney test; $U_A$ = value of U at 95% confidence limit of 17–67; $P_I$ = level of probability for accepting null hypothesis for $U_A$.
[a]Lower values of total iron binding capacity, serum cholesterol, serum albumin, nPCR, serum alkaline phosphatase, and Kt/V are indicative of malnutrition—inflammation burden and therefore have higher numerical scores.

were 0.15 for OMIS I and 0.04 for OMIS II (see Table 6), indicating a much smaller typical error for OMIS II. Intra-class correlation coefficient for change in the mean score of the repeated scores was 0.95, indicating a high degree of reliability between OMIS I and OMIS II. The scoring system had a moderate sensitivity of 62.5% and a very good specificity (83%). Accuracy was 75% while precision (or positive predictive value) was 71%. Regression analysis (Table 7) showed that dialysis adequacy, alkaline phosphatase, BMI, and TIBC had the strongest correlation with CRP (Kt/V, $\beta = 0.61$ ($p = 0.05$); alkaline phosphatase, $\beta = -0.40$ ($p = 0.01$); BMI, $\beta = -0.34$($p = 0.02$); and TIBC, $\beta = 0.30$ ($p = 0.03$)). The negative relationship with BMI indicates there is higher score for those with less body mass (suggesting nutritional deficit). Due to a higher numerical score assigned (HD = 1, PD = 0), the negative value of beta coefficient suggests there is greater inflammatory burden in HD patients. There was a modest contribution from serum albumin, frequency and severity of infection, primary renal pathology, serum ferritin, and nPCR. The paradoxical finding of a negative relationship with serum alkaline phosphatase (despite a p-value < 0.01) is most probably due to confounding effect of parathyroid hormone on bone metabolism.[14]

The overall impact of all explanatory variables on OMIS II model (12-item) is impressive, producing an $R^2 = 0.9$ and a >80% goodness of fit ($F = 4.3$, $p = 0.03$). Multi-collinearity (correlation among the diagnostic indices) may explain the lower values of beta coefficient despite the significance of overall model. OMIS I (9-item score) has a less robust model with $R^2$ of 0.75 (and goodness of fit was <80%).

**Table 5.** Analysis of the indices of malnutrition—inflammation morbidity in pediatric dialysis cohort using serum C-reactive protein (CRP) as a binary outcome predictor.

| Diagnostic indices[a] | Raw data ± 95% CL | | Mann–Whitney | |
|---|---|---|---|---|
| | Normal CRP (n = 12) | High CRP (n = 8) | $U_A$ (95% CL = 22–74) | $P_I$ |
| Serum ferritin (mg/dL) | 816 (473–1159) | 1151 (728–1571) | 76 | 0.044 |
| Hemoglobin (g/dL) | 10.8 (9.8–11.8) | 9.9 (8.6–11.2) | 27 | 0.060 |
| Total iron binding capacity | 231 (193–268) | 181 (151–211) | 11 | 0.002 |
| Serum albumin (g/dL) | 3.5 (3.19–3.81) | 3.0 (−2.3 to 3.7) | 8 | 0.001 |
| Normalized protein catabolic rate (nPCR) | 1.2 (0.75–1.7) | 0.7 (0.5–0.90) | 14 | 0.004 |
| Serum cholesterol (mg/dL) | 164 (147–171) | 152 (122–182) | 27 | 0.060 |
| Serum alkaline phosphatase (mg/dL) | 325.5 (175–465) | 457.6 (22.6–891) | 38 | 0.230 |
| Dialysis adequacy (Kt/V) | 0.1 (−0.12 to 0.3) | 0.2 (−0.13 to 0.63) | 34 | 0.150 |
| Dialysis duration (months) | 29.4 (16.4–42.4) | 30.3 (10.1–49.2) | 65 | 0.102 |
| Renal pathology score | 1.40 (0.6–2.2) | 1.50 (0.40–1.6) | 72 | 0.110 |
| Infection score | 0.04 (−0.05 to 0.11) | 0.68 (−0.12 to 1.5) | 96 | 0.0001 |

CL: confidence limit.
Serum CRP: normal = <0.3 mg/dL; high = >0.3 mg/dL.
U: Mann–Whitney test; $U_A$ = value of U at 95% CL of 22–74; $P_I$ = level of probability for accepting null hypothesis for $U_A$.
[a]Lower values of total iron binding capacity, serum cholesterol, serum albumin, nPCR, serum alkaline phosphatase, and Kt/V are indicative of greater malnutrition—inflammation burden.

Although F value (4.1) and level of significance (p = 0.01) were equivalent for both instruments, the greater value of the intercept (2.2 vs 1.6) for OMIS II (12-item) showed there was a direct benefit for inclusion of more variables in the model.

## Discussion

Persistent inflammation, metabolic derangements and nutritional inadequacies promote the progression of protein energy wasting in chronic kidney disease population. In addition to the short-term morbidity, malnutrition—inflammation complex is associated with lower physical quality-of-life indices and higher mortality rate in the renal population.[15] Due to uremic oxidative stress, chronic kidney disease patients are susceptible to spatial memory (cognitive) dysfunction[16] while close to 50% of children and adolescents fail to attain the normal adult height.[17,18] In view of the uremic–catabolic process, interventional strategies that are limited to the correction of nutritional deficit are often inadequate. In addition to measures that are aimed at optimizing removal of middle molecule toxins (dialysis), institution of supportive anti-oxidative therapy may be invaluable in selected patients.[19] In this regard, accurate assessment of the burden of malnutrition and inflammation is necessary for optimal care, reduction of morbidity and mortality, and maximization of growth potential.[20]

In this study, we have provided a template for a composite scoring of MIM in a pilot study of a pediatric cohort on chronic dialysis. To ascertain clinical relevance of the tool, we selected laboratory indicators of nutritional deficiency that are routinely obtained in dialysis patients. We also scored common clinical items that have pro-inflammatory attributes such as longer length of dialysis exposure. To avoid confounding effect of cognitive capacity on accuracy of data, we avoided all items that require subjective responses.[8] This is particularly important in view of wide variation in the developmental achievements of children with chronic diseases.[21,22]

We assessed two scoring systems, one with 9 items (OMIS I; p = 0.01) and the other (12-item OMIS II) with an additional 3 items (p = 0.03). As an evidence for concurrent-criterion validity, both demonstrated strong predictive relationship with CRP in multiple regression analysis (Table 7). Due to the small sample size, our goal is not to select the most predictive set of items, a task that could be performed in a stepwise logistic regression model. Nevertheless, we chose 12-item OMIS II for subsequent analysis because it scored higher on reliability testing, had stronger goodness of fit, and demonstrated a more robust model. Furthermore, a valid instrument must demonstrate strong reliability by maintaining a consistent outcome with repeat testing. Using test–retest method, there is a very small typical error and an excellent correlation coefficient (r = 0.96) for the two datasets. Diagnostic value of OMIS II was calculated: it had a moderate sensitivity of 62.5% but a high specificity of 83%.

In support of biological plausibility of the model, there were lower serum values of TIBC, nPCR, and serum cholesterol while serum ferritin, dialysis duration, and infection rate had higher scores among patients with greater value of CRP (Table 5). Similarly, in agreement with existing evidence, there were higher scores for diagnostic indices of malnutrition—inflammation in HD patients than those on PD (Table 4).[23] On the contrary, the lower serum value (or higher score) of albumin in PD patients may be due to excess protein losses in dialysates.

**Table 6.** Test–retest reliability: correlation between repeated measures of malnutrition—inflammation scores at 1-month interval.

| Test–retest data | Change in mean score (M2–M1)[a] | Typical error |
|---|---|---|
| OMIS I | 0.15 (0.02–0.3) | 0.22 (0.18–0.3) |
| OMIS II | 0.04 (0.0–0.08) | 0.07 (0.06–0.1) |
| Correlation coefficient, r | 0.95 (0.9–0.98) | 0.96 (0.91–0.98) |

OMIS I: 9-item objective malnutrition—inflammation score; OMIS II: 12-item objective malnutrition—inflammation score (including the initial nine items for OMIS I); M2: mean of the score obtained after a repeat measurement of the selected items for OMIS at 1-month interval; M1: mean value of the initial scoring of the selected items.

[a]Change in the mean score after 1-month interval (M2–M1) of a log transformed data; Intra-class correlation coefficient, r, is derived from the changes in mean score of each selected item (M1 and M2) at 1-month interval. The value of the random variation in monthly measurements of each selected item per subject (or typical error) is interpreted as small if <0.2 and extremely large if >4.0.

**Table 7.** Regression analysis of items used for composite scoring of malnutrition—inflammation morbidity (OMIS II) in pediatric dialysis cohort using serum C-reactive protein as outcome variable.

| Items scored | β-coefficient | Standard error | t-stat | p | 95% CI |
|---|---|---|---|---|---|
| Intercept | 1.6 | 0.37 | 4.4 | 0.003 | 0.7 to 2.50 |
| Body mass index | −0.34 | 0.11 | −2.93 | 0.02 | −0.6 to −0.1 |
| Total iron binding capacity | 0.30 | 0.10 | 2.70 | 0.03 | 0.04 to 0.55 |
| Serum albumin (g/dL) | −0.20 | 0.10 | −2.13 | 0.07 | −0.41 to 0.02 |
| Infection score | 0.15 | 0.10 | 1.50 | 0.18 | −0.10 to 0.41 |
| Renal pathology score | 0.03 | 0.07 | 0.47 | 0.67 | −0.14 to 0.20 |
| Dialysis modality | −0.40 | 0.21 | −1.82 | 0.11 | −0.91 to 0.11 |
| Dialysis adequacy (Kt/V) | 0.61 | 0.25 | 2.40 | 0.05 | 0.01 to 1.22 |
| Serum ferritin (mg/dL) | 0.06 | 0.07 | 0.88 | 0.41 | −0.10 to 0.22 |
| Length of dialysis (months) | 0.12 | 0.09 | 1.30 | 0.23 | −0.09 to 0.33 |
| Normalized protein catabolic rate | −0.24 | 0.12 | −1.98 | 0.09 | −0.52 to 0.04 |
| Serum cholesterol (mg/dL) | 0.15 | 0.12 | 1.20 | 0.27 | −0.14 to 0.44 |
| Serum alkaline phosphatase (mg/dL) | −0.40 | 0.10 | −3.80 | 0.01 | −0.63 to 0.15 |

OMIS II: 12-item objective malnutrition—inflammation score; CI: confidence interval.

$R^2 = 0.9$; goodness of fit = >0.80; sum of square = 3.7; mean square = 0.31; F statistic = 4.3; p = 0.03.

The major weakness of our study is the inadequacy of serum CRP to serve as a surrogate measure of malnutrition—inflammation complex. However, this is a universal problem in all criterion-validation studies. Due to the complex pathophysiological process in dialysis patients, there is no perfect choice of a single parameter that could serve as a gold standard. This may account for the modest value obtained on the calculation of the diagnostic sensitivity of the instrument. Nevertheless, CRP has been widely studied as a marker of inflammation in different clinical settings, and it is the most credible predictor of long-term outcome.[11,24] Finally, the small sample size of the study is understandable as our goal is to provide a template for a more comprehensive study in a larger population of pediatric dialysis cohort.

In summary, although there are many laboratory tools available to determine the nutritional burden of pediatric patients undergoing dialysis, altered body fluid status and pro-inflammatory confounding factors limit their reliability. Our pilot study demonstrates the feasibility of using multi-diagnostic approach to collect an accurate but cost-effective data with a potential for universal applicability. We encourage large-scale population-specific studies for validation of its clinical effectiveness and for refinement of the selected diagnostic items.

## Declaration of conflicting interests

The authors declare that there is no conflict of interest.

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