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# Pretransplant Malnutrition, Particularly With Muscle Depletion Is Associated With Adverse Outcomes After Kidney Transplantation

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**Background.** Kidney transplant centers lack consistent diagnostic malnutrition tools. The Academy of Nutrition and Dietetics and American Society of Parenteral Nutrition Adult Malnutrition Criteria (AMC) is the widely accepted and utilized tool by Registered Dietitian Nutritionists (RDNs) to diagnose malnutrition. **Methods.** In this single-center, retrospective observational study, we evaluated the outcomes of prekidney transplant malnutrition based on Academy of Nutrition and Dietetics and American Society of Parenteral Nutrition AMC, as well as the individual components of the AMC, on posttransplant outcomes including length of stay, delayed graft function (DGF), early readmission, cardiovascular events, acute rejection, death-censored graft failure, and death. Bivariable and multivariable logistic regression models were used to assess the association of malnutrition or its components with outcomes of interest. **Results.** A total of 367 recipients were included, of whom 36 (10%) were malnourished (23 moderately and 13 severely) at pretransplant evaluation. In adjusted models, pretransplant malnutrition was significantly associated with increased risk for early readmission (adjusted odds ratio 2.86; 95% confidence interval: 1.14-7.21; $P = 0.03$) and with DGF (adjusted odds ratio 8.33; 95% confidence interval: 1.07-64.6; $P = 0.04$). Muscle depletion was also associated with an increased risk for readmission and with DGF. Fat depletion and reduced functionality in the adjusted model were only associated with increased risk for readmission. **Conclusions.** Malnutrition could be an important consideration for selecting kidney transplant recipients because it was associated with poor clinical outcomes. A multidisciplinary approach with the involvement of RDNs to outline a nutrition intervention plan may help mitigate some of the poor outcomes.

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Malnutrition is diagnosed in the presence of nutritional imbalance or undernutrition due to disease process, medical condition, or environmental factors.[1-3] The etiology occurs along a continuum of inadequate intake and/or increased caloric requirements, impaired absorption, altered transport, and altered nutrient utilization resulting in reduced nutrition reserve.[1] Although there is no universal tool to diagnose malnutrition, the most commonly used tools among Registered Dietitian Nutritionists (RDNs) are the Subjective Global Assessment, the Global Leadership Initiative on Malnutrition, and the Adult Malnutrition Criteria (abbreviated AMC for the purposes of this study) recognized by the Academy of Nutrition and Dietetics (AND) and the American Society for Parenteral and Enteral Nutrition (ASPEN).[1-3] Historically and in clinical practice, albumin or body mass index (BMI) have been used as indicators for malnutrition. However, multiple studies suggest that albumin should not be used as a sole indicator of nutrition status and malnutrition can be present at any BMI.[1,4]

In 2012, the AND published a consensus statement to propose the universal use of a single diagnostic tool to recognize malnutrition, guide interventions, and correlate expected outcomes.[5] This tool, known as the AND/ASPEN AMC, includes a Nutrition Focused Physical Exam (NFPE) assessing muscle and fat depletion, fluid retention, and a detailed nutrition assessment to determine the etiology and severity of malnutrition. When applicable, measurement of hand grip strength (HGS; from the frailty assessment) is included. RDNs, whose

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credentialing includes rigorous training on this tool, have implemented and utilized the AMC in hospitals and other healthcare settings across the United States as the standard for malnutrition diagnosis.

Kidney disease increases the risk of developing malnutrition because of the hypermetabolic demands of disease processes, increased inflammatory and catabolic cytokines, and dietary restrictions. Additionally, patients with chronic kidney disease and patients on dialysis are at higher risk for food insecurity.[6] These etiologies can result in loss of muscle and fat reserves.[2] The prevalence of malnutrition is high in general hospitalized, critically ill, and geriatric populations, and is especially high in end-stage organ failure.[2] Research using the AMC is lacking among kidney transplant patient populations and is needed to quantify risks, outcomes, and costs associated with malnutrition given the high prevalence in end-stage organ diseases. Our hypothesis was that kidney transplant recipients with pretransplant malnutrition would have poor posttransplant outcomes.

In this study, the impact of prekidney transplant malnutrition (using the AMC tool) on posttransplant outcomes was determined, including posttransplant length of stay (LOS), delayed graft function (DGF), early readmission, cardiovascular events, acute rejection, death-censored graft failure (DCGF), and death. Additionally, it was determined which of the diagnostic components of the AMC (with the exemption of fluid retention) is most strongly associated with negative posttransplant outcomes.

## MATERIALS AND METHODS

The Wisconsin Allograft Recipient Database (WisARD) was initiated to collect information on all solid organ transplantations performed at the University of Wisconsin. The current retrospective observational study includes all adult kidney-only transplant recipients transplanted between June 2016 and December 2020 who received a full diagnostic malnutrition assessment by an RDN. Outcomes of interest included LOS after transplant, DGF, early readmission, any cardiovascular events, acute rejection, DCGF, and death. Information collected on the patients included: gender, race, age at the time of transplant, cause of end-stage kidney disease (ESKD), and history of previous transplant. DGF was defined as the need for dialysis within the first 7 d of kidney transplantation.[7] Early readmission included any overnight hospital stay within 30 d of the initial posttransplant discharge. Cardiovascular events included congestive heart failure, acute coronary symptoms, abnormal heart rhythm, as well as other events. All acute rejections were biopsy-proven. DCGF was defined as the initiation of dialysis or retransplantation before the end of the data analysis. All deaths were deaths with a functional allograft. The malnutrition assessment closest to the transplant admission was used for analysis. This study was approved by the University of Wisconsin School of Medicine and Public Health Institutional Review Board (protocol number: 2014-1072). This study was in adherence to the Declaration of Helsinki. The clinical and research activities being reported were consistent with the Principles of the Declaration of Istanbul as outlined in "The Declaration of Istanbul on Organ Trafficking and Transplant Tourism."

### Diagnosing Malnutrition

All kidney transplant recipients receive a nutrition assessment. The RDN completes a malnutrition assessment which includes an additional NFPE. First, the etiology of malnutrition is determined as either (1) acute or (2) chronic illness or injury (in the presence of inflammation) or (3) environmental-related factors (social determinants of health). Next, 2 of 6 diagnostic criteria, including unintentional weight loss, energy intake, body fat depletion, muscle mass depletion, fluid accumulation, and/or reduced functional status (measured by HGS), must be met to diagnose malnutrition.[1] Based on the severity of those 2 characteristics, malnutrition can be diagnosed as either moderate (nonsevere) or severe.[1] There is not a diagnosis of mild malnutrition. The cutoff values for reduced HGS by the Fried Frailty Phenotype (used for frailty assessment) are based on age and BMI and can be used as one criteria for diagnosis of severe malnutrition.[8] Although fluid accumulation is used as a criterion for malnutrition, the diagnosis of volume excess and estimation of dry weight is based largely on clinical criteria and has an extremely poor diagnostic accuracy among patients with chronic kidney disease (CKD)/ESKD.[9] Therefore, fluid assessment was not used as a criteria in this study and rather, 2 of 5 criteria were used for diagnosis. Patients diagnosed with malnutrition were told of their diagnosis and counseled on ways to improve this and recommended to follow up with RDN in their dialysis center locally.

### Data Collection of Malnutrition Assessment

Malnutrition assessments were performed by the transplant dietitian during their pretransplant evaluation in the ambulatory clinic. Malnutrition was assessed among potential kidney transplant recipients in 2016, beginning, as case by case. It took a few years to fully implement the malnutrition assessment on all potential candidates. Also, during the initial wave of the COVID-19 pandemic, to decrease patient contact, most of the evaluations were done virtually or with minimal patient contact limiting further malnutrition assessment. Malnutrition assessment and scores were discussed during pretransplant selection meetings and considered as one of the factors in deciding transplant candidacy. Patients on the waitlist were re-evaluated every 1–2 y, including the malnutrition assessment. Patients with malnutrition or those at high risk for developing malnutrition were assessed at least yearly. The RDN completed a thorough assessment including weight and diet history, an NFPE to assess muscle and fat depletion, and a HGS test as part of the Fried Frailty Phenotype assessment to evaluate each component necessary for malnutrition diagnosis. Also, RDNs assess frailty utilizing a modified Fried Frailty Phenotype as described before.[10]

Data collection was completed by four transplant RDNs. Patients were assigned a grade of 0 for the absence of malnutrition, a grade of 1 for moderate malnutrition, and a grade of 2 for severe malnutrition. Each individual criterion was scored as 1 if present. Diagnosis and resolution date (if applicable) were recorded.

### Immunosuppressive Protocols

As previously described, our kidney transplant recipients receive induction with either a depleting agent or a nondepleting agent, followed by a triple immunosuppressant regimen consisting of tacrolimus, mycophenolic acid, and prednisone.[11]

The choice of induction agent is based on pretransplant immunological risk factors. At no time has induction or maintenance immunosuppression been based on malnutrition.

### Allograft Biopsy and Rejection Protocols

Most biopsies are performed for cause, such as unexplained rise in serum creatinine or proteinuria.[12] Protocol biopsies are performed at 3- and 12-mo posttransplant on patients with pretransplant donor-specific antibodies and on patients with de novo donor-specific antibodies posttransplant. Rejection treatment is based on the severity of both antibody-mediated rejection and acute T cell–mediated rejection as previously described.[13]

### Posttransplant Follow-up

After discharge from an initial kidney transplant, patients are typically seen by the transplant provider at 3 wk, 6 wk, 3 mo, 6 mo, 9 mo, 12 mo, 18 mo, 24 mo, and then annually. Kidney transplant recipients are followed at either the University Hospital or various regional outreach clinics at least annually until graft failure or the patients decide to transfer their care to a different provider.

## STATISTICAL ANALYSIS

Categorical data were analyzed and presented as an absolute number and percentage, whereas continuous variables were presented as mean and SD. Baseline characteristics were compared using chi-squared tests or *t*-tests, as appropriate. Bivariable and multivariable logistic regression models were used to assess the association of malnutrition or its individual components with outcomes of interest. Some of the significant outcomes were also presented as a Kaplan–Meier survival curve. Multivariable models included recipients' sex, race, cause of ESKD (diabetes versus other), sum frailty ≥1; previous transplant, living donor, human leukocyte antigen mismatch, calculated panel-reactive antibody, depleting induction, kidney cold time, and recipient's BMI. Results with a very wide range of odds ratio (OR) either in univariable or multivariable analysis were not presented. The correlation between LOS and individual components of malnutrition was calculated using Spearman's rank correlation coefficient. All analyses were performed using the MedCalc Statistical Software version 16.4.3 (MedCalc Software, Ostend, Belgium; https://www.medcalc.org; 2016).

## RESULTS

A total of 367 kidney transplant recipients had a pretransplant malnutrition assessment as part of their pretransplant evaluation. Their baseline characteristics are shown in Table 1. None of the recipients in the malnutrition group were frail with a sum frailty score of ≥3. In the malnourished group, 12 (33%) had a sum frailty score of 1, and 5 (14%) had a sum frailty score of 2. Likewise, among the nonmalnourished group, only 1 recipient was frail with a sum frailty score of 3, 14 (4%) had a sum frailty score of 2, and 72 (22%) had a sum frailty score of 1. Malnutrition was diagnosed 9.7 ± 6.8 mo before transplant (Table 2). A total of 36 recipients (10%) were malnourished before transplant, 23 (6%) of which were moderately malnourished and 13 (4%) were severely malnourished, as shown in Table 2. The most common component of malnutrition was muscle depletion, which was found in all 36 recipients. In unadjusted analyses, malnutrition was

**TABLE 1.**

**Baseline clinical characteristics**

| Variables | All | Malnourished | No-malnourished | *P* |
|---|---|---|---|---|
| Total no. recipients assessed for malnutrition | 367 | 36 | 331 | |
| Male (%) | 230 (63) | 22 (61) | 208 (63) | 0.84 |
| White (%) | 283 (77) | 29 (81) | 254 (77) | 0.61 |
| Age at transplant | 55.8 ± 12.7 | 59.9 ± 9.8 | 55.3 ± 12.9 | **0.04** |
| Cause of ESKD (%) | | | | 0.15 |
| Diabetes | 119 (32) | 13 (36) | 106 (32) | |
| Hypertension | 49 (13) | 6 (17) | 43 (13) | |
| Glomerulonephritis | 83 (23) | 3 (8) | 80 (24) | |
| Polycystic kidney disease | 52 (14) | 4 (11) | 48 (15) | |
| Other | 64 (17) | 10 (28) | 54 (16) | |
| Previous transplant recipients (%) | 61 (17) | 12 (33) | 49 (15) | **0.005** |
| Sum frailty score ≥ 1 (total assessed 261) | 34 (13) | 9 (30) | 25 (11) | **0.003** |
| Living donor (%) | 154 (42) | 16 (44) | 138 (42) | 0.75 |
| Recipients BMI (kg/m$^2$) | 28.4 ± 5.3 | 24.5 ± 4.0 | 28.8 ± 5.3 | **<0.001** |
| Mean KDPI among deceased donor (%) | 51.5 ± 27.1 | 52.3 ± 26.5 | 51.5 ± 27.2 | 0.89 |
| Mean HLA mismatch of 6 | 3.8 ± 1.5 | 3.7 ± 1.9 | 3.8 ± 1.4 | 0.64 |
| cPRA > 20% | 77 (21) | 8 (22) | 69 (21) | 0.85 |
| Cold ischemia time (h) | 10.9 ± 7.5 | 10.5 ± 6.5 | 11.0 ± 7.6 | 0.70 |
| Induction agent | | | | **0.002** |
| Basiliximab | 111 (30) | 16 (44) | 96 (29) | |
| Antithymocyte globulin | 175 (48) | 17 (47) | 158 (48) | |
| Alemtuzumab | 80 (22) | 3 (8) | 77 (23) | |
| Early steroid withdrawal | 75 (20) | 7 (19) | 68 (21) | 0.88 |
| Mean posttransplant hospital stay (d) | 5.2 ± 2.2 | 5.3 ± 2.0 | 5.2 ± 2.3 | 0.76 |

Bold values indicate statistical significance with $P < 0.5$.
BMI, body mass index; cPRA, calculated panel-reactive antibody; ESKD, end-stage kidney disease; KPDI, kidney donor profile index.

**TABLE 2.**
**Malnutrition assessment**

| Variables | |
|---|---|
| Mean interval from malnutrition assessment to transplant (mo) | 9.7 ± 6.8 |
| Malnutrition (%) | |
| Yes | 36 (10) |
| Grade of malnutrition | |
| 0—None | 331 (90) |
| 1—Moderate | 23 (6) |
| 2—Severe | 13 (4) |
| Weight loss | |
| 0[a] | 349 (95) |
| 1[b] | 18 (5) |
| Muscle depletion | |
| 0 | 331 (90) |
| 1 | 36 (10) |
| Fat depletion | |
| 0 | 349 (95) |
| 1 | 18 (5) |
| Poor oral intake | |
| 0 | 348 (95) |
| 1 | 19 (5) |
| Reduced functionality | |
| 0 | 365 (99) |
| 1 | 2 (1) |

[a] 0 indicates not present.
[b] 1 indicates present.

**TABLE 3.**
**Length of stay**

| | Correlation coefficient (95% CI) |
|---|---|
| Weight loss | 0.04 (–0.06 to 0.15; $P = 0.41$) |
| Muscle depletion | 0.06 (–0.04 to 0.16; $P = 0.22$) |
| Fat depletion | 0.02 (–0.09 to 0.12; $P = 0.74$) |
| Poor oral intake | 0.06 (–0.04 to 0.16; $P = 0.24$) |
| Reduced functionality | 0.09 (–0.004 to 0.19; $P = 0.06$) |

CI, confidence interval.

significantly associated with increased risk for early readmission (OR 2.08; 95% confidence interval [CI]: 1.1-3.89; $P = 0.02$) and cardiovascular events (OR 2.40; 95% CI: 1.24-4.64; $P = 0.009$) (Table 3; Figures 1 and 2). After adjustment for multiple variables, malnutrition was still associated with early readmission (adjusted OR [aOR] 2.86; 95% CI: 1.14-7.21; $P = 0.03$) and was also associated with DGF (aOR: 8.33; 95% CI: 1.07-64.6; $P = 0.04$).

## Length of Stay

The mean LOS among the entire cohort was 5.22 ± 2.24 d, and the mean LOS among the malnutrition group was 5.0 ± 1.99 d. None of the diagnostic components of malnutrition were significantly associated with prolonged or reduced LOS (Table 4).

## Delayed Graft Function

A total of 34 recipients (9%) had DGF, 4 (11%) of whom were malnourished. In an adjusted model, only muscle depletion was associated with increased risk for DGF (aOR 8.33; 95% CI: 1.07-64.65; $P = 0.04$) (Table 5).

## Early Readmission

A total of 69 (19%) recipients had early readmission, of whom 12 (33.3%) of 36 were in the malnutrition group (Table 6). The most common indication for readmission was gastrointestinal symptoms (5 recipients), urinary symptoms (3 recipients), and 1 recipient for each of the following: hyperglycemia, elevated serum creatinine, fluid collection around the graft, and stroke as an indication for early readmission. In the unadjusted model, weight loss and muscle depletion were associated with an increased risk for early readmission. Differences in readmission rates based on muscle depletion was confirmed with Kaplan–Meier survival analysis (Figure 3). After adjustment for multiple variables, muscle depletion (OR: 5.21; 95% CI:42-8.65; $P = 0.006$); fat depletion (OR: 4.19; 95% CI: 1.01-17.56; $P = 0.04$), and reduced functionality (OR: 15.1; 95% CI: 1.39-163.8; $P = 0.02$) were associated with early readmission.

## Cardiovascular Events

A total of 57 (16%) recipients in the entire cohort had cardiovascular events requiring hospitalization during the study period (Table 7). Eleven (30.5%) of 36 recipients in the malnutrition group had cardiovascular events, with the most common event being abnormal heart rhythm (5 recipients), myocardial infarction (3 recipients), and issues with fluid retention. In the unadjusted model, weight loss and muscle depletion were associated with increased risk for cardiovascular events. The association between muscle depletion and increased risk for cardiovascular events was confirmed with the Kaplan–Meier survival analysis curve (Figure 4). However, after adjustment of various factors, none of the 5 components of malnutrition was associated with either increased or decreased risk for cardiovascular events.

## Acute Rejection

A total of 66 (18%) recipients had acute rejection during the study period, and 7 (19%) of 36 recipients were in the malnutrition group (Table 8). None of the diagnostic variables for malnutrition were significantly associated with acute rejection.

## DCGF and Death with Functioning Graft

A total of 30 (9%) recipients had kidney DCGF (3/36; 8% in the malnutrition group), and 42 recipients (11%) died with functional grafts (2/36; 5% in the malnutrition group). None of the diagnostic variables for malnutrition were significantly associated with DCGF or death (Tables 9 and 10).

# DISCUSSION

In this large series of 367 kidney transplant recipients who underwent malnutrition assessments in the pretransplant evaluation using the AND/ASPEN AMC, malnutrition was significantly associated with early readmission and DGF in adjusted models. Of note, these associations were independent of frailty. The association between malnutrition and cardiovascular events lost statistical significance after adjustment for confounding variables, including frailty. Of the 5 diagnostic criteria for malnutrition, muscle depletion was significantly associated with early readmission and DGF in adjusted models, and cardiovascular events in unadjusted models. Regarding the other diagnostic criteria, fat depletion, weight loss, and

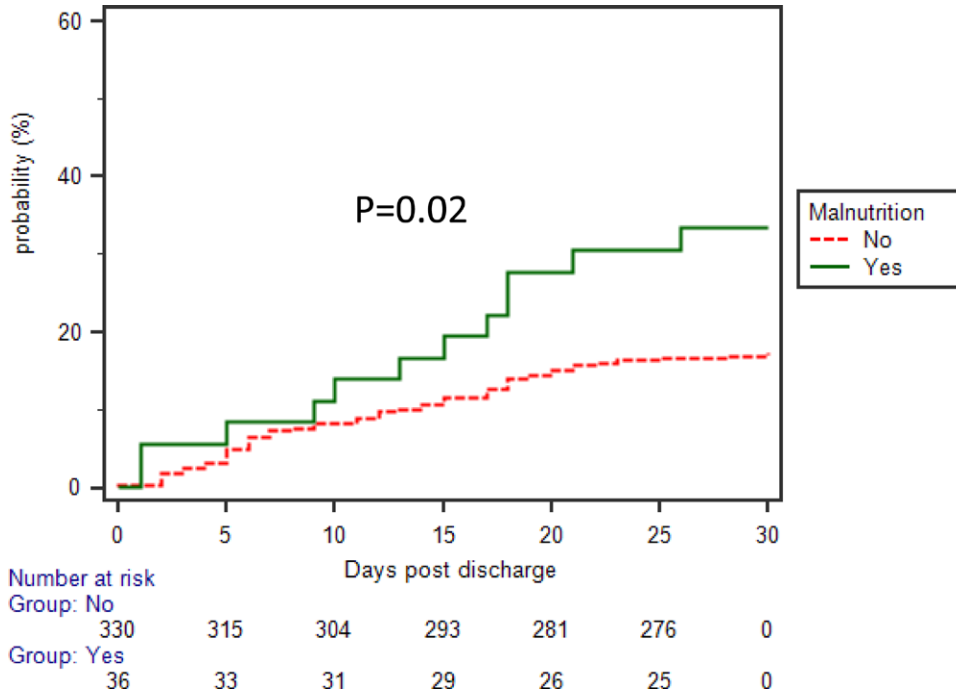


**FIGURE 1.** Recipients with pretransplant malnourishment were significantly associated with increased risk for readmission ($P = 0.02$).

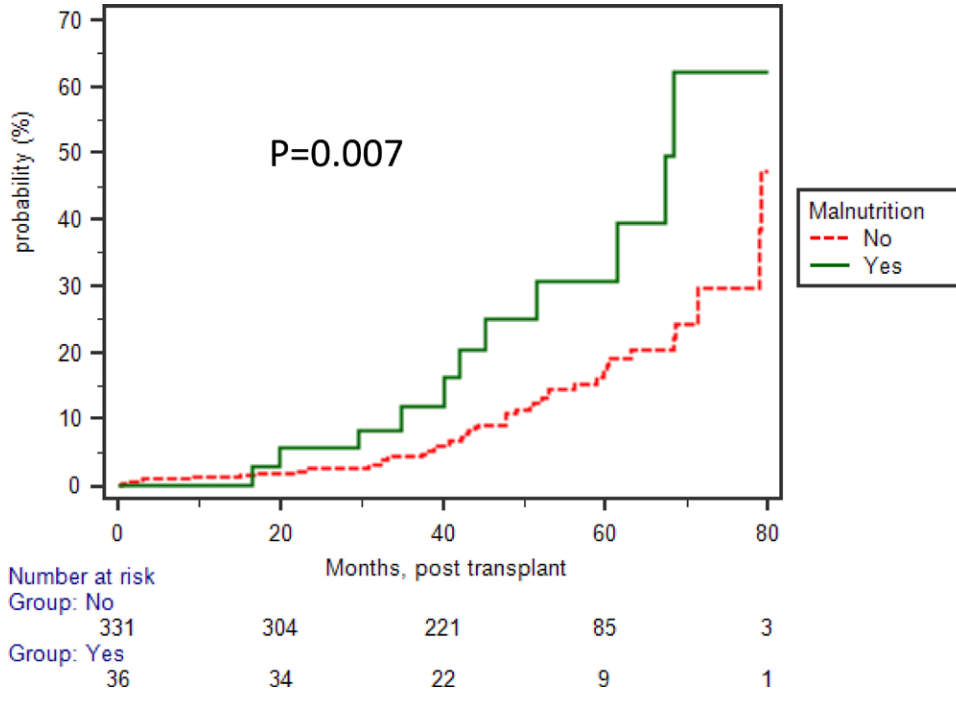


**FIGURE 2.** Recipients with pretransplant malnourishment were significantly associated with an increased risk of having cardiovascular events ($P = 0.007$).

reduced functionality were associated with negative posttransplant outcomes including early DGF, early readmission, and cardiovascular events, whereas inadequate oral intake was not associated with any negative posttransplant outcomes. Not surprisingly, neither overall malnutrition nor any of its individual components were associated with rejection.

Malnutrition in general patient populations is associated with adverse outcomes including increased morbidity and mortality, increased infection rates, poor wound healing, significantly higher healthcare utilization, significantly longer LOS, decreased function, and decreased quality of life.[1,14] Hospital costs for malnutrition are estimated to be 73% higher than those without malnutrition.[14] For malnourished patients, the 30-d readmission rate was 1.4 times higher, and patients were 2 times more likely to be discharged to long-term care facilities.[14] Additionally, patients with malnutrition

**TABLE 4.**

**Association between malnutrition diagnosis and clinical outcomes**

| | Malnutrition | |
|---|---|---|
| | **OR (unadjusted)** | **OR (adjusted)** |
| DGF | 1.17 (0.41–3.33; $P = 0.77$) | **8.33 (1.07–64.6; $P = 0.04$)** |
| Early readmission | **2.08 (1.11–3.89; $P = 0.02$)** | **2.86 (1.14–7.21; $P = 0.03$)** |
| Cardiovascular events | **2.40 (1.24–4.64; $P = 0.009$)** | 1.59 (0.59–4.27; $P = 0.35$) |
| Acute rejection | 1.07 (0.49–2.36; $P = 0.85$) | 1.14 (0.36–3.62; $P = 0.81$) |
| Death-censored graft failure | 1.00 (0.30–3.33; $P = 0.99$) | 0.26 (0.02–3.07; $P = 0.29$) |
| Death with functioning graft | 0.46 (0.11–1.92) | 0.16 (0.02–1.34; $P = 0.09$) |

Bold values indicate statistical significance with $P < 0.5$.
DGF, delayed graft function; OR, odds ratio.

**TABLE 5.**

**Association with DGF (n = 34, 9%)**

| | **OR (unadjusted)** | **OR (adjusted)** |
|---|---|---|
| Weight loss | 1.75 (0.53–5.79; $P = 0.35$) | 2.98 (0.34–25.91, $P = 0.32$) |
| Muscle depletion | 1.17 (0.41–3.35; $P = 0.76$) | **8.33 (1.07–64.65; $P = 0.04$)** |
| Fat depletion | 1.35 (0.41–4.48; $P = 0.63$) | — |
| Poor oral intake | 1.24 (0.29–5.31; $P = 0.77$) | 4.18 (0.46–37.96; $P = 0.20$) |
| Reduced functionality | **9.60 (1.25–73.27; $P = 0.03$)** | — |

Bold values indicate statistical significance with $P < 0.5$.
DGF, delayed graft function; OR, odds ratio.

**TABLE 6.**

**Association with early readmission (n = 69, 19%)**

| | **OR (unadjusted)** | **OR (adjusted)** |
|---|---|---|
| Weight loss | **2.71 (1.29–5.66; $P = 0.008$)** | 1.90 (0.66–5.50; $P = 0.23$) |
| Muscle depletion | **2.36 (1.29–4.31; $P = 0.005$)** | **3.51 (1.42–8.65; $P = 0.006$)** |
| Fat depletion | 1.21 (0.44–3.31; $P = 0.71$) | **4.19 (1.01–17.56; $P = 0.04$)** |
| Poor oral intake | 1.89 (0.82–4.37; $P = 0.14$) | 1.86 (0.58–6.01; $P = 0.30$) |
| Reduced functionality | 3.89 (0.54–28.11; $P = 0.18$) | **15.1 (1.39–163.8; $P = 0.02$)** |

Bold values indicate statistical significance with $P < 0.5$.
OR, odds ratio.

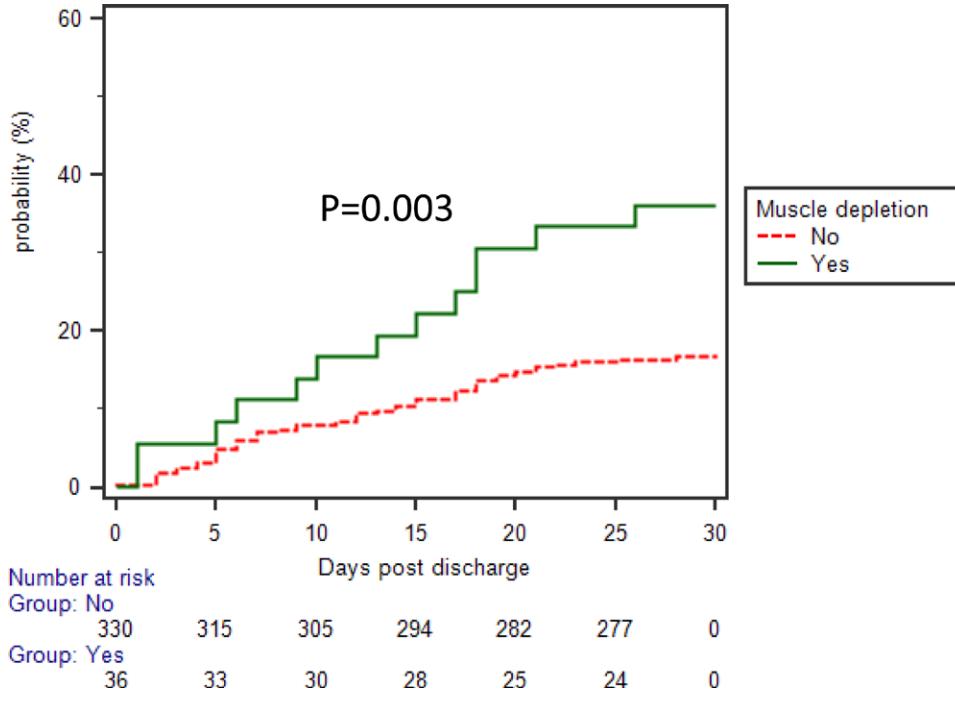


**FIGURE 3.** Recipients with pretransplant muscle depletion were significantly associated with increased risk for readmission ($P = 0.003$).

**TABLE 7.**

**Association with cardiovascular events (n = 57; 16%)**

| | OR (unadjusted) | OR (adjusted) |
|---|---|---|
| Weight loss | **3.02 (1.42–6.41; *P* = 0.004)** | 1.62 (0.59–4.44; *P* = 0.35) |
| Muscle depletion | **2.69 (1.42–5.11; *P* = 0.002)** | 2.02 (0.77–5.29; *P* = 0.14) |
| Fat depletion | 1.86 (0.74–4.68; *P* = 0.19) | 1.23 (0.24–6.27; *P* = 0.80) |
| Poor oral intake | 1.99 (0.79–5.01; *P* = 0.14) | 1.57 (0.41–5.93; *P* = 0.51) |
| Reduced functionality | — | — |

Bold values indicate statistical significance with $P < 0.5$.
OR, odds ratio.

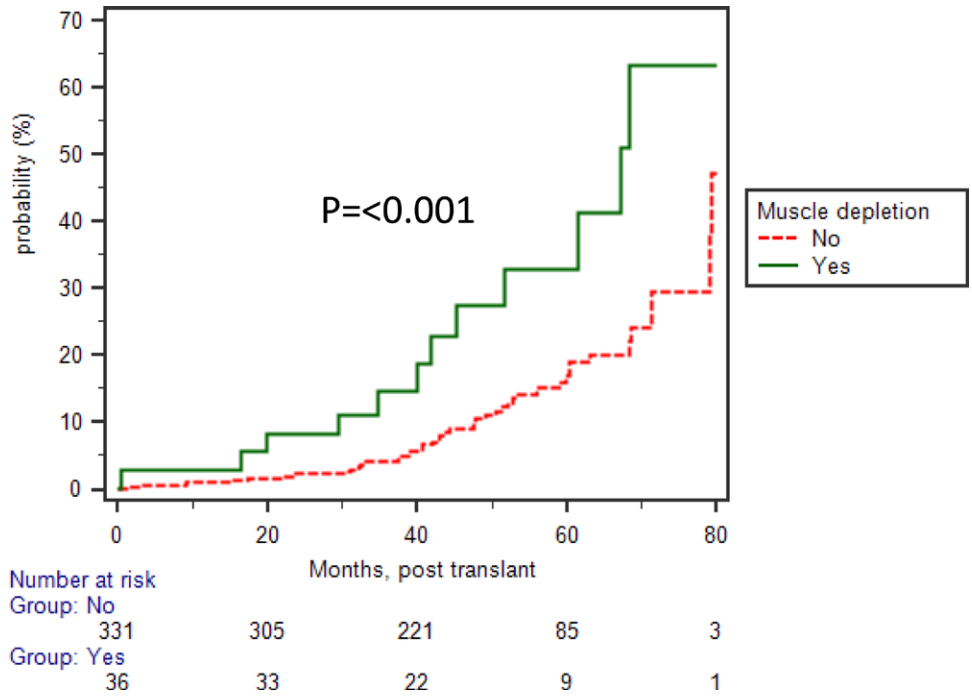


**FIGURE 4.** Recipients with pretransplant muscle depletion were significantly associated with an increased risk of having cardiovascular events ($P \leq 0.001$).

**TABLE 8.**

**Association with acute rejection (n = 66; 18%)**

| | OR (unadjusted) | OR (adjusted) |
|---|---|---|
| Weight loss | 1.37 (0.55–3.43; *P* = 0.49) | 0.69 (0.17–2.75; *P* = 0.60) |
| Muscle depletion | 1.09 (0.49–2.39; *P* = 0.83) | 1.14 (0.96–1.01; *P* = 0.99) |
| Fat depletion | 0.78 (0.24–2.51; *P* = 0.68) | 0.69 (0.08–6.0; *P* = 0.74) |
| Poor oral intake | 1.22 (0.44–3.40; *P* = 0.70) | 2.32 (0.72–7.51; *P* = 0.16) |
| Reduced functionality | — | — |

OR, odds ratio.

**TABLE 9.**

**Association with death-censored graft failure (n = 30, 9%)**

| | OR (unadjusted) | OR (adjusted) |
|---|---|---|
| Weight loss | 1.29 (0.31–5.43; *P* = 0.73) | — |
| Muscle depletion | 1.03 (0.96–3.41; *P* = 0.96) | 0.26 (0.02–3.08; *P* = 0.29) |
| Fat depletion | 1.24 (0.29–5.26; *P* = 0.76) | 1.67 (0.15–18.79; *P* = 0.68) |
| Poor oral intake | 0.65 (0.08–4.88; *P* = 0.67) | — |
| Reduced functionality | — | — |

OR, odds ratio.

**TABLE 10.**

**Association for death (n = 42, 11%)**

| | OR (unadjusted) | OR (adjusted) |
|---|---|---|
| Weight loss | 0.43 (0.06–3.12; $P = 0.41$) | 0.29 (0.04–2.28; $P = 0.24$) |
| Muscle depletion | 0.73 (0.22–2.36; $P = 0.60$) | 0.38 (0.08–1.84; $P = 0.23$) |
| Fat depletion | 0.47 (0.06–3.44; $P = 0.46$) | — |
| Poor oral intake | 0.47 (0.06–3.42; $P = 0.46$) | 0.35 (0.04–2.99; $P = 0.35$) |
| Reduced functionality | — | — |

OR, odds ratio.

had an average LOS of 9 d compared with 4.7 d ($P < 0.0001$) for patients who are nonmalnourished.[14] This aligns with the study finding that muscle depletion in malnutrition is associated with readmission.[15]

Malnutrition risk increases as CKD progresses through ESKD and dialysis initiation. The prevalence of malnutrition among hemodialysis patients ranges between 28% and 52% and additional global estimates of malnutrition among patients with CKD stages 3–5 (not on dialysis) were 11%–54%.[16] Uremic symptoms including poor appetite, altered taste, fatigue, and nausea associated with CKD (not on dialysis), may contribute to inadequate oral intake, unintentional weight loss, and reduced muscle and fat stores. Once dialysis is initiated, the risk for malnutrition is further exacerbated because of ongoing poor appetite, hypermetabolic demands and nutrient losses, inflammation, metabolic acidosis, malabsorption, psychosocial and financial barriers, low diet quality from diet restrictions, and difficulty with food preparation.[17] Likely because of stringent selection criteria, only 10% of the population in this study were malnourished at the time of transplant which is less than would be expected. Patients who were found to be malnourished in the pretransplant evaluation may not have been approved for transplant in conjunction with other contraindications or relative risks. Severe malnutrition often has other comorbidities and these candidates could have been denied because of a severely cachectic state, severe frailty, cardiac risk, or advanced age.

There are limited research on kidney transplant candidates with malnutrition using AMC criteria; however, frailty and sarcopenia have been thoroughly researched, with muscle wasting and loss of function being key indicators for diagnosis.[18] Frailty in kidney transplant recipients is associated with DGF, longer LOS, early hospital readmission, immunosuppression intolerance, and impaired functioning.[19] Frailty is found in 14% of patients with CKD, 47% with ESKD, 71% with ESKD over the age of 65 y, and approximately 15%–20% of kidney transplant recipients are frail at the time of transplant.[20,21] Frailty is independently associated with 2.17-fold risk of death and according to a 2021 retrospective cohort study, patients who were both frail and had lean tissue wasting were 2.56 times more likely to be removed from the waiting list.[18,22] Low HGS and slow gait speed are the most predictive of outcomes.[10] Frailty and malnutrition etiology are closely intertwined and therefore is reasonable to expect similar outcomes for kidney transplant recipients with malnutrition.

Sarcopenia, age-related muscle mass, and quality wasting with functional capacity changes increase with ESKD compared with CKD counterparts because of disease and inflammation-related protein degradation.[23] Sarcopenia is associated with worse quality of life and higher hospitalization and mortality rates.[24] Slowed gait speed and reduced HGS are associated with increased risk of all-cause mortality, with 1 study demonstrating a 50% 2-y mortality rate in hemodialysis patients >75 y of age with severe sarcopenia and muscle wasting.[25] This demonstrates the correlation between negative outcomes with loss of muscle mass and function which is consistent with malnutrition and frailty research.

In this study, we report pretransplant malnutrition, and particularly muscle depletion to be associated with increased risk for DGF. Although we do not have the exact mechanism for this, however, it could be related to multiple etiology including malnourishment associated with increased risk for poor wound healing and calcineurin toxicity which is more prevalent in malnourished patients and many more which all contribute to DGF.[26,27] Even in the general population, malnourished patients were more likely to be readmitted after initial hospital discharge, which was consistent to our findings among transplant recipients.[15]

This study has the expected limitations of a single-center observational study. Our findings are reflective of specific practices at one center, which should be factored into interpretation. Another limitation is there was insufficient data to analyze the average period of time for malnutrition resolution after transplant and to analyze outcomes based on malnutrition severity. Also, this study was focused on post-transplant outcomes. The outcomes among potential candidates who were evaluated but did not receive transplants were not included. Additionally, not all recipients during the study period had a full NFPE—to assess for malnutrition, which could lead to selection bias.

In summary, we found that malnutrition using the AMC criteria is significantly associated with early readmission and DGF. Of the 5 diagnostic components for this tool, muscle depletion was significantly associated with several poor outcomes. These findings are consistent with previous research on malnutrition, sarcopenia, and frailty in the general and CKD/ESKD population. To our knowledge, this is the first study analyzing postkidney transplant outcomes related to malnutrition using this diagnostic tool, despite being one of the most widely utilized tools by RDNs across the US transplant centers and hospitals.[28] Much of the current literature focuses on frailty status, and these findings remained significant outside of frailty status.

## Future Implications

Based on previous research and the findings from our study, we propose that every nutrition assessment by the RDN should include a malnutrition assessment (with NFPE) using a diagnostic tool, such as the AND/ASPEN AMC, with a proposed treatment plan to improve malnutrition if applicable. Serial malnutrition assessments can be easily completed and

contribute to nutritional status trends. When accepting or denying patients for listing, malnutrition, and especially muscle depletion should be considered to inform nutrition treatment plans before and after transplant, given it is associated with poor outcomes. Improving malnutrition for optimizing posttransplant outcomes should be directed by the RDN and requires collaboration with the multidisciplinary team. This involves focusing on minimizing the catabolic effect of the disease by increasing calorie and protein intake, improving nutrient utilization and absorption, and building nutrition reserve.

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