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CPE Using a Web-Based Nutrition Algorithm in Hemodialysis Patients

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Objectives: The purpose of this study was to test the ability of a newly developed nutrition algorithm on (1) clinical utility and (2) ability to capture patient outcomes.

Research Design: This was a prospective observational study, using a practice based research network structure, involving renal dietitians and hemodialysis [HD] patients.

Setting: This study took place in HD outpatient units in five different countries.

Subjects: Hundred chronic HD patients were included in this study. To select subjects, dietitians screened and consented patients in their facilities until 4 patients "at nutrition risk" based on the algorithm screening tool were identified. Inclusion criteria were patients aged older than 19 years, not on hospice or equivalent, able to read the informed consent and ask questions, and receiving HD.

Main Outcome Measure: The ability of the algorithm screening tool is to identify patients at nutrition risk, to guide clinicians in logical renal-modified nutrition care process chains including follow-up on relevant parameters, and capture change in outcomes over 3 months. Statistics were performed using SPSS version 20.0 and significance was set at $P < .05$.

Results: One hundred patients on HD, enrolled by 29 dietitians, were included in this analysis. The average number of out-of-range screening parameters per patient was 3.7 (standard deviation 1.5, range 1-7), and the most prevalent risk factors were elevated parathyroid hormone (PTH; 62.8%) and low serum cholesterol (56.5%). At the initial screening step, 8 of the 14 factors led to chains with nonrandom selection patterns (by χ^2 test with $P < .05$). In the subsequent diagnosis step, patients diagnosed within the insufficient protein group ($n = 38$), increased protein intake by 0.11 g/kg/day ($P = .022$). In patients with a diagnosis in the high PTH group, PTH decreased by a mean of 176.85 pg/mL ($n = 19$, $P = .011$) and in those with a diagnosis in the high phosphorous group, serum phosphorous decreased by a mean of 0.91 mg/dL ($n = 33$, $P = .006$). Finally, the relative likelihood of each assessment being completed after making the related diagnosis at the previous visit compared with those for whom that diagnosis was not made was assessed, including the likelihood of a patient's protein intake assessed after a diagnosis in the insufficient protein group was made (odds ratio = 4.08, $P < .05$).

Conclusions: This study demonstrates the clinical utility of a web-based HD-specific nutrition algorithm, including the ability to track changes in outcomes over time. There is potential for future research to use this tool and investigate the comparative impact of nutrition interventions.

This article has an online CPE activity available at www.kidney.org/professionals/CRN/ceuMain.cfm

Related Commentary, p. 75

Introduction

NUTRITION STATUS IS closely associated with hospitalization and mortality in hemodialysis (HD) patients. Data have shown that patients who are malnourished are more likely to be hospitalized and that the hospital stay has a negative impact on patients' nutritional status, with approximately 25% unable to recover this additional nutritional status loss.[1] Similarly, patients diagnosed with protein energy wasting (PEW) are more likely to die.[2,3] Specifically, each 1 g/dL decrease in serum albumin concentration has been related to a 177% increased risk of mortality and 67% increased risk of hospitalization in these patients.[4] Furthermore, nutrition abnormalities, including alterations in phosphatemia, parathyroid function, calcemia, kalemia, fluid status, and lipid profile, are responsible for a substantial risk of morbidity and mortality in HD patients.[5–10]

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Clinical guidelines for nutrition in Chronic Kidney Disease (CKD) including the National Kidney Foundation's Kidney/Dialysis Outcomes Quality Initiative,[11] the European Society of Parenteral and Enteral Nutrition,[12] and regulatory guidelines from the Centers for Medicaid and Medicare Conditions for Coverage for End Stage Renal Disease Facilities[13] recommend that HD patients be routinely assessed for signs of altered nutrition status.

To date, there is a paucity of randomized clinical trials where correction of nutrition abnormality results in decreased mortality. However, we suggest that, to reduce the risk of death in HD patients, identification and treatment of nutrition abnormalities needs to occur frequently and in a systematic way that is driven by evidence-based practice considerations.

This nutrition algorithm (Fig. 1) was created to address the need for systematic and consistent treatment of nutrition abnormalities in CKD while capturing patient outcomes. The algorithm is a computerized clinical decision support system designed to aid in identification of HD patents at risk for nutrition abnormalities and guide clinical decisions at each step of a renal-modified Nutrition Care Process (NCP): assessing patient data, diagnosing nutrition problems, determining the problems' etiology, intervening to resolve those problems, and monitoring and evaluating patient progress,[14] and is accessed via a web-based graphical user interface.

Figure 1 provides a graphical representation of the algorithm's process, delineating computerized suggestions and clinician decisions. This process is a modification from the original NCP as it includes a barrier step; therefore, for the purposes of this article, it is called as a renal-modified NCP. An example of options presented by the algorithm at each step based on a hypothetical set of clinician inputs is also presented in Figure 1. The screening step requests a fixed set of patient data[15] that are compared with internal reference ranges to identify patients at risk for nutrition abnormalities.

At each subsequent step, the algorithm uses data entered during the previous steps and programmed logic to select a subset from the list of available options for display, and the clinician determines which options are selected. The available options for the diagnosis, etiologies, barriers, intervention, and monitoring/evaluation steps were taken from or adapted from the International Dietetics and Nutrition Terminology (IDNT) Reference Manual.[16] Adaptations and/or additions were made by a renal practice expert on the research team (J.B.L.) and approved by the other researchers. Some assessment terms, which are well validated in HD patients, notably Subjective Global Assessment (SGA) score,[17] did not correspond well with existing IDNT assessment terminology at the time of the study but were still included as assessment options. Although the etiology is not a named step in the NCP, identification

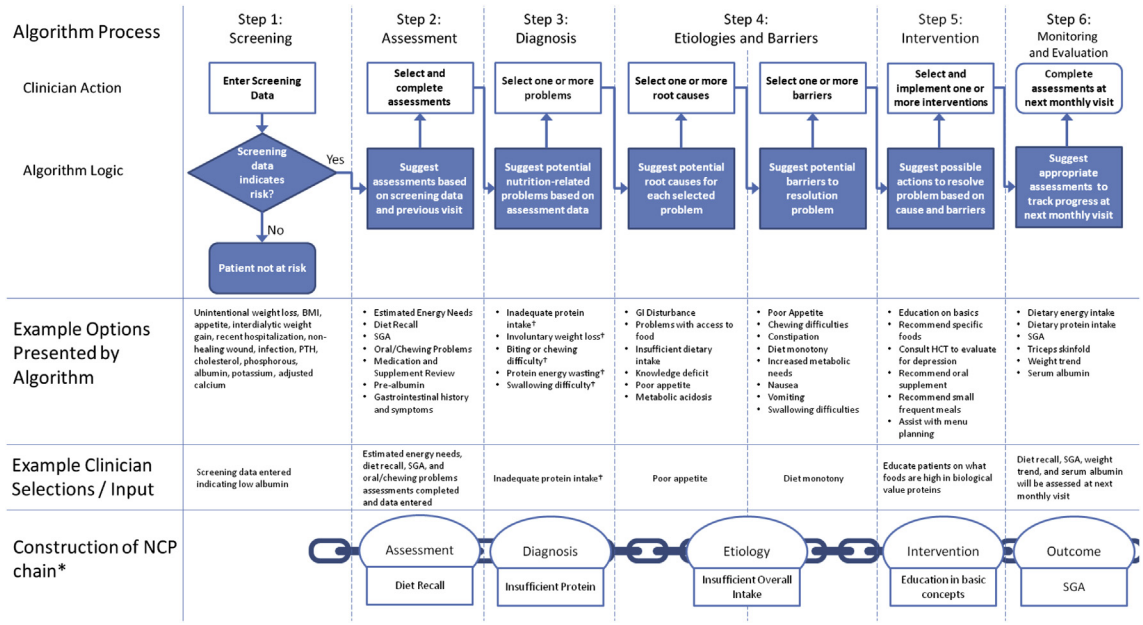

Figure 1. Flowchart description of the algorithm used in this study accompanied by an example subset of options offered by the algorithm at each step based on a set of hypothetical clinician inputs and the relationship of those inputs to the formation of a renal-modified NCP chain. Shaded flowchart boxes indicate computerized action and hollow boxes indicate clinician input. *NCP chain construct adapted from Hakel-Smith, Lewis, and Eskridge.[20] †Example options presented by the algorithm include standardized language from the International Dietetics and Nutrition Terminology reference manual.[18] BMI, body mass index; HCT, health care team; NCP, Academy of Nutrition and Dietetics's Nutrition Care Process (REF); PTH, serum intact parathyroid hormone; SGA, Subjective Global Assessment (REF).

of cause/contributing risk factors is described, and the etiology is a key component of the nutrition diagnostic statement (following the pattern problem/etiology/signs and symptoms).[16] As described in the IDNT manual,[16] the same terms were used as options for diagnoses and etiologies in our algorithm. In this article, the individual terms are not being listed; alternatively, the IDNT terms have been grouped for easier presentation and analysis. For example, the IDNT terms relating to low protein status or intake have been "grouped" into insufficient protein, which is not in of itself an IDNT term. The addition of a barriers step between etiologies and interventions was based on previous work in overcoming barriers in HD patients.[18] Because of the limited scope of the interventions listed in the second edition of the IDNT manual[16] (now greatly expanded in current editions), the interventions options were expanded and made specific for this population. The same assessment terminology was used to describe options for monitoring and evaluation; the reassessment of these parameters at serial points is referred to as outcomes in this article. The logic used to link inputs at each step of the algorithm to suggestions at the subsequent step was determined by the matrices accompanying the IDNT Manual and expert opinion.

Figure 1 also depicts the formation of a renal-modified NCP chain, a construct adapted from Hakel-Smith, Lewis, and Eskridge.[19] Renal-modified NCP chains were used to organize data collected by the algorithm to support comparison of the usage of the algorithm between clinicians.

The purpose of this pilot trial was to determine clinical feasibility of the algorithm in both international and US HD patients.

Methods

This was a prospective study in patients with CKD receiving HD in five countries. There were two aims of this study: (1) to assess the clinical utility of the algorithm and (2) to assess whether the algorithm could capture changes in nutrition-related outcomes. These aims and their respective research questions, method of assessment, and expected outcomes are described in Table 1. The first aim was evaluated in terms of the algorithm's ability to detect patients who are at risk, the validity of that risk assessment, evidence of logical thought produced via the algorithm's clinical decision support system. The second aim was evaluated in terms of the algorithm's ability to successfully capture follow-up data, relate that data to previous visits, and demonstrate changes in patient outcome measures over time.

Dietitian Researchers

As described previously,[20] email invitations were sent to renal dietitians who had expressed interest in participating in research or who were employees of specific dialysis organizations in the United States. Dietitians representing HD units based in five different countries including the US participated (Table 2). Dietitians who participated in the study were trained on use of the web-based nutrition algorithm and in human subjects' protection. Training on the use of the nutrition algorithm was accomplished during a 1-hour webinar, which included a discussion of the NCP, how to enter data into the algorithm, and how to advance through the steps of the algorithm. Additionally, dietitians were provided written material on the NCP as well as routine email and phone support from the principal investigator and study coordinator throughout the study. Feedback from the dietitians was solicited during regular conference calls, and some alterations to the algorithm (e.g., the ability to revert to a previous step to correct data entry errors) were made during the course of the study.

Table 1. Study Aims and Objectives

Aim	Measurement Tool	Research Question	Hypothesized Outcome
1. Clinical utility			
	Algorithm	(a) Does the algorithm identify risk factors?	Patients with screening parameters outside normal ranges will be identified as at risk.
		(b) Is the risk identified by the algorithm valid?	A correlation between number of risk factors identified by the algorithm and a surrogate endpoint for morbidity and mortality (serum albumin) will be observed.
		(c) Are the renal-modified NCP chains that are constructed logical?	Nonrandom patterns in dietitian selections at each step of the algorithm will be observed.
2. Capture patient outcomes			
	Algorithm	(a) Were data relevant to the progress of nutrition problems identified in the first visit successfully collected at a later visit?	Patients will be more likely to have risk factors related to diagnoses at visit 1 assessed at follow-up than patients without these diagnoses.
		(b) Were differences in outcomes at 3 mo measurable using the algorithm?	Changes in outcome parameters related to the most frequently identified nutrition diagnoses will be captured at 3 mo.

NCP, Nutrition Care Process.

Table 2. Sample Demographics and Key Clinical Data by Country

	Total Sample	United States of America	New Zealand	Ireland	Australia	Brazil
Demographic data *N* (%)						
Gender (*n*)	100	60	25	7	4	4
Male	55 (55.0)	36 (60.0)	11 (56.0)	4 (57.1)	2 (50.0)	2 (50.0)
Female	45 (45.0)	24 (40.0)	14 (44.0)	3 (42.9)	2 (50.0)	2 (50.0)
Race/ethnicity (*n*)	98	60	23	7	4	4
Caucasian	59 (60.2)	35 (58.3)	13 (56.5)	6 (85.7)	2 (50.0)	3 (75.0)
Black	12 (12.2)	11 (18.3)	0 (0.0)	1 (14.3)	0 (0.0)	0 (0.0)
Hispanic	7 (7.1)	7 (11.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Asian	4 (4.1)	2 (3.3)	2 (8.7)	0 (0.0)	0 (0.0)	0 (0.0)
Other/multiracial	16 (16.3)	5 (8.3)	8 (34.8)	0 (0.0)	2 (50.0)	1 (25.0)
Clinical data (mean ± SD)						
Age (y) ($n = 100$)	61 ± 15.0	60.5 ± 13.9	63.5 ± 16.9	61.1 ± 13.8	61.3 ± 21.5	54.2 ± 1.9
Dialysis vintage (y) ($n = 74$)	4.0 ± 4.5	3.8 ± 4.6	5.1 ± 5.2	3.8 ± 2.0	Not available	Not available
Body mass index (kg/m^2) ($n = 97$)	29.7 ± 8.4	31.5 ± 9.2	26.7 ± 6.2	27.8 ± 7.8	28.4 ± 8.6	26.4 ± 4.8
Serum albumin (g/dL BCG) ($n = 99$)	3.9 ± 0.4	3.9 ± 0.4a	3.8 ± 0.4b	3.7 ± 0.5	3.3 ± 0.3ab	4.0 ± 0.2
Serum phosphorus (mg/dL) ($n = 100$)	5.2 ± 1.5	5.3 ± 1.4	5.2 ± 1.8	5.4 ± 1.9	5.4 ± 0.7	4.5 ± 1.1

BCG, bromocresol green assay; SD, standard deviation.
Gender and race/ethnicity data presented as number of patients. Clinical data presented as mean ± standard deviation.
Alphabets across columns denote statistically significant difference via one-way analysis of variance with Tukey *post hoc* test ($P < .05$).

Institutional Review Board

This study had primary Institutional Review Board approval from Case Western Reserve University (CWRU) and subsequent approvals from the international and US-based dialysis units or chains. All subjects completed written informed consent in English with explanation by the researcher in the participants' native language.

Subjects

To select study subjects, dietitians were asked to consent and screen every fifth patient using an alphabetized list of patients in their facilities until 4 patients were identified by the algorithm as at nutrition risk (having at least 1 abnormal screening parameter). Inclusion criteria for the patients were greater than 19 years of age, not on hospice care, or equivalent, receiving HD at a facility with a dietitian participating in the study, and identified as at nutritional risk during the first screening using the online algorithm screening tool. The dietitians followed their study patients with the algorithm monthly for 3 months from baseline. At baseline, patients had to be at nutrition risk to be included in the study but patients who were no longer at risk during study follow-up visits continued to be screened monthly for the appearance of other risk factors.

Data Collection

All patient and renal-modified NCP chain data were collected via the nutrition algorithm's web-based interface and stored on servers located at CWRU. However, most participating dietitians in this phase did not have a computer available at chair side, so paper versions of the screening tool and assessment forms were provided. Data were collected on these forms and then entered into the algorithm (Fig. 2A and B) before proceeding to the next step.

Dietitians were assigned codes and passwords for access into the algorithm. Patient data entered into online database did not contain the patient's name, address, or any medical number used by their facility for identification. Data from all of the patients could be downloaded into excel files by the researchers at CWRU. However, each individual dietitian could only access information from his or her patients. Demographic data such as birth and dialysis start date, race or ethnicity, were collected at the baseline only.

The first step of the algorithm, the screening tool, requested the same set of data at each visit: height, dry weight, current post-HD weight, post-HD weight 1, 3, and 6 months prior, body mass index, occurrence of unintentional weight loss, occurrence of excessive interdialytic weight gain, history of amputation, use of erythropoietin stimulating agent, complaint and degree of poor appetite, presence of nonhealing wound, signs or symptoms of infection, report of overnight hospitalization in the prior month, and routine serum chemistries (albumin, phosphorous, PTH, potassium, cholesterol, hemoglobin, glycated hemoglobin, and calcium). However, the algorithm did not require that all screening parameters be entered to support both clinician discretion in determining what data to enter and differences in data availability.

The assessment step of the algorithm collected additional patient data by recommending specific parameters to collect or review based on the out-of-range parameters in the screening tool. There were 24 potential assessments, including 24-hour dietary recall data, estimated total

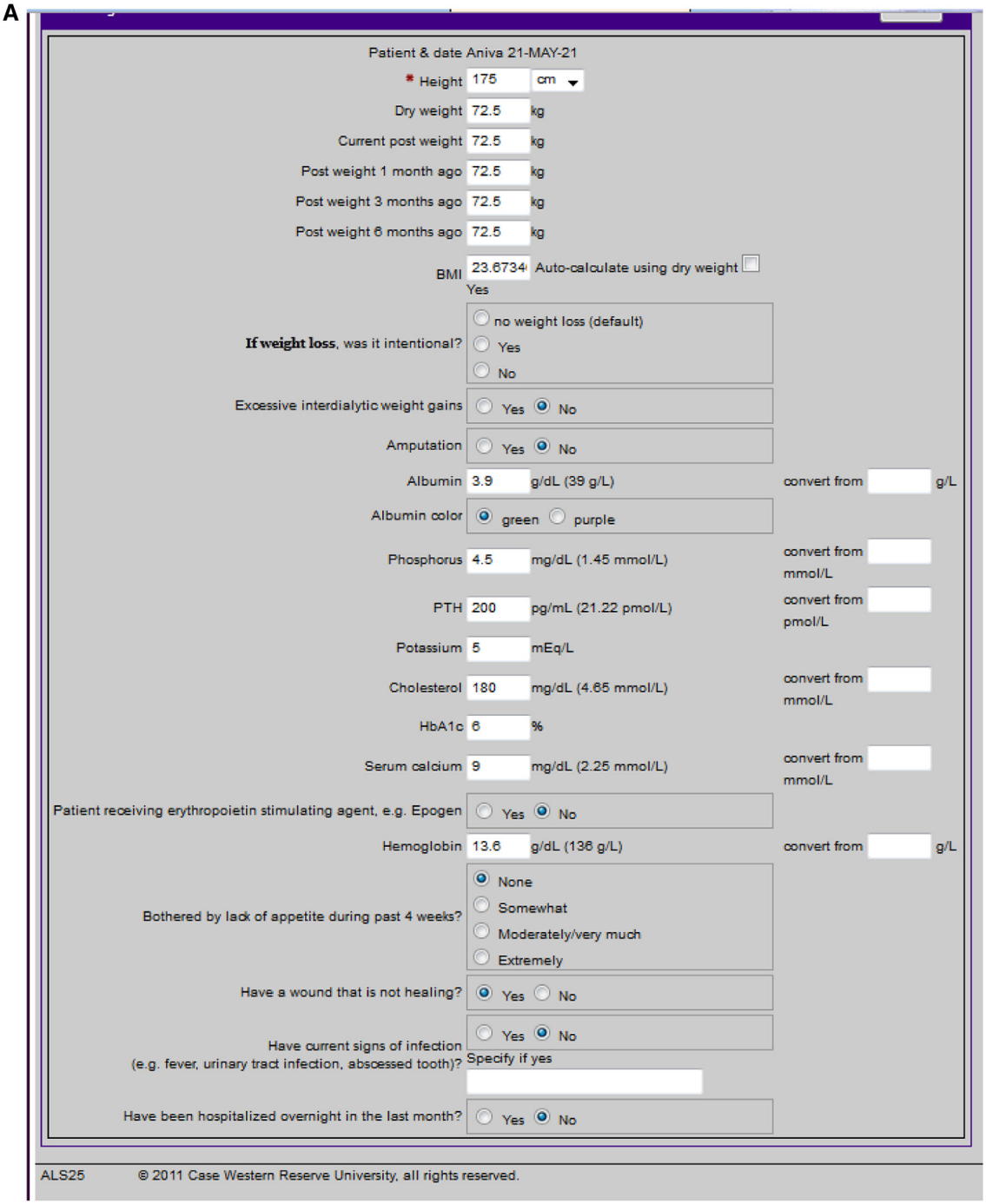

Figure 2. (A) Screen image capture of the screening step in the algorithm's web-based user interface. (B) Screen image capture of a completed visit the algorithm's web-based user interface.

energy expenditure, SGA score, and serum albumin. The algorithm provided recommendations for parameters but the assessments performed or reported depended on dietitian discretion.

The dietitians used the biochemical and anthropometric values from their usual laboratory reports and/or medical records. To ensure whether comparable data were available for analysis, the assay type (bromocresol purple or bromocresol green) used for serum albumin was also collected, and bromocresol purple results were converted for comparison with bromocresol green results by adding 0.3.[4] Biochemical data entered in international units (SI) were automatically converted to conventional units by the algorithm.

In addition to patient data, clinical decision mapping data were captured by the algorithm for analysis. At the

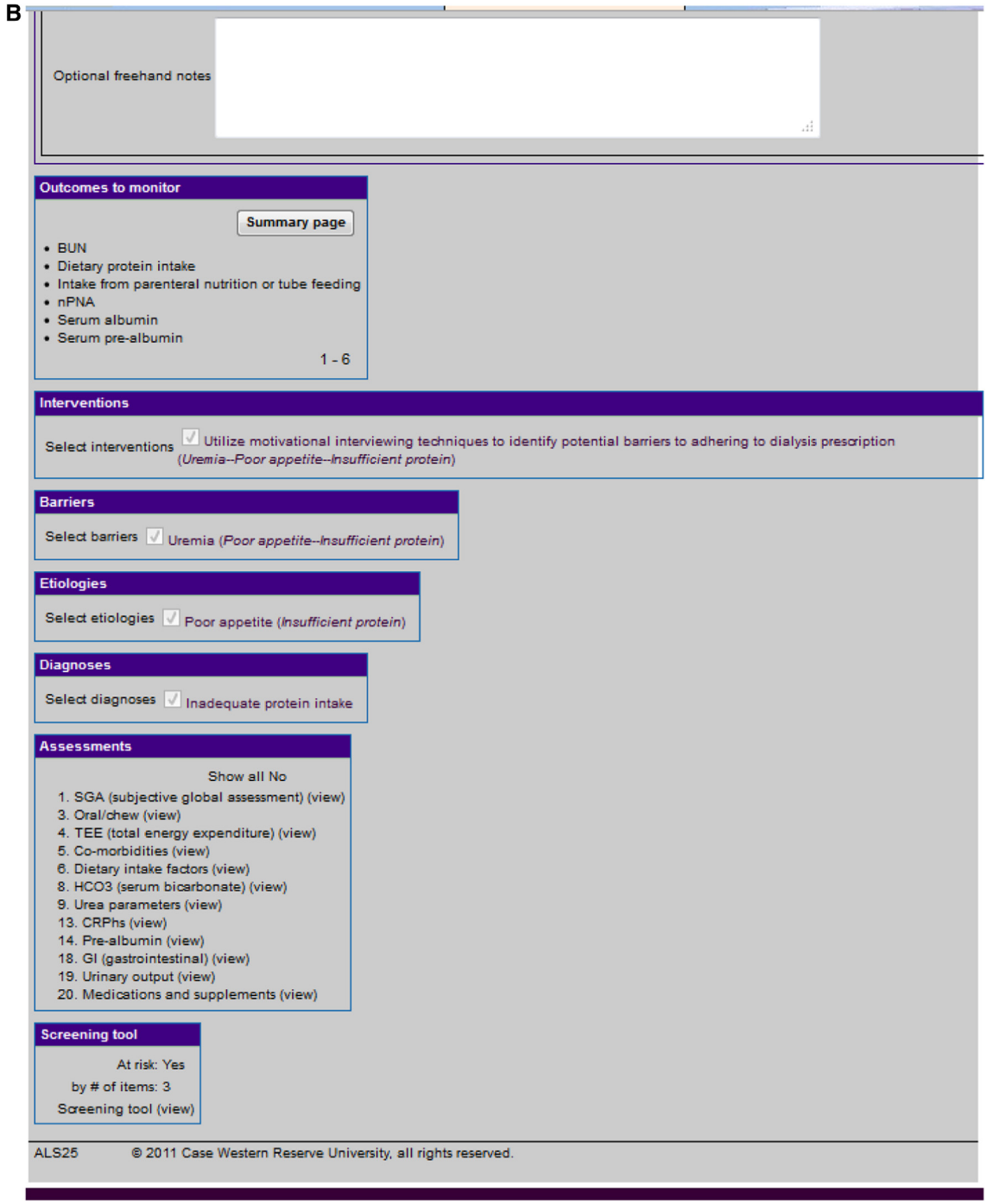

Figure 2. (*continued*).

diagnosis, etiologies, barriers, and intervention steps, the dietitians selected options from a list of recommendations provided by the algorithm. Because of the large number of individual options at each step (60, 43, 94, and 220, respectively), each option was assigned to a group, defined *a priori*, and selections from within each of the groups (17, 6, 10, and 12, respectively) were considered identical when defining NCP chains and analyzing treatment patterns. Although the dietitians were presented with the exact terms from the IDNT along with custom terms for this study (such as SGA score) to select from, the groupings presented here do not reflect the terminology of the IDNT, but rather groupings of related terms created for this analysis. No data were collected for the monitoring/evaluation step but this step helped determine what data should be collected during the next visit's assessment step—any assessments that were

out of range at 1 visit would be suggested as parameters to collect when the next visit occurred.

Data Analysis

Statistics were performed using SPSS version 20.0 (IBM Inc, New York, 2011) with α set at 0.05. Analyses follow the aims identified in Table 1. Descriptive statistics (*n*, percent) are reported on the distribution of risk factors (i.e., number of out-of-range screening parameters) across patients to determine whether the algorithm is accurately identifying patients at risk based on screening measures outside the clinical threshold (aim 1a). Validation of this measure for nutrition risk was assessed via Spearman correlation between serum albumin level and numbers of risk factors identified with the expectation that more risk factors should be associated with a lower albumin (aim 1b). Nutrition care and treatment patterns were analyzed for nonrandom selection patterns via χ^2 tests at each step of the NCP chains (aim 1c). Beginning with the most commonly identified risk factors, χ^2 tests were performed to determine if dietitians were more likely to select particular options at the subsequent NCP step. To determine whether the algorithm was useful for tracking patient changes over time (aim 2a), odds ratios (OR) of the dietitian assessing key outcomes at 3 months given that the patient had been given a related diagnosis at the first visit were calculated. Finally, the ability of the algorithm to capture patient outcomes (aim 2B) was assessed via paired *t*-tests or Wilcoxon signed rank tests, depending on the observed distributions, to determine if those outcomes (weight, SGA score, energy intake, protein intake, albumin, PTH, and phosphorous) changed significantly between visit 1 and 3 months (and hence, whether the algorithm could capture such changes).

Results

One hundred patients, enrolled by 29 dietitians, were included in this analysis, and the demographic and key baseline clinical data of the patients are presented in Table 2. The screening parameters, reference ranges, and prevalence of each risk factor are listed in Table 3. The average number of out-of-range screening parameters, indicating nutrition risk in that parameter, per patient was 3.7 (standard deviation 1.5, range 1-7). The most prevalent risk factors were elevated PTH (62.8%) and low serum cholesterol (56.5%). We found a significant weak negative relationship (rho = −0.228, $P = .023$) between serum albumin and the number of risk factors identified by the algorithm.

Table 4 presents NCP chains for risk factors with at least 30% prevalence and indicates when the association between a particular group of terms at 1 step of the NCP is significantly associated with the most common selection at the next NCP step. For example, of the patients with an albumin of less than 3.8 mg/dL (37% of those with available data), 73% ($P < .0001$) were given a nutrition diagnosis within the insufficient protein intake group. All 8 of the risk factors listed led to chains with nonrandom selection

Table 3. Nutritional Risk Screening Parameters

Parameter (Range Considered at Risk)	*N* With Data	*N* at risk	% With Risk*	Mean (SD) in Entire Sample	Mean (SD) Within Specific at Risk Ranges
PTH (<100 or >300 pg/mL)	94	68	73.4	519.9 (602.7)	—
>300 pg/mL	94	59	62.8	—	730.8 (675.7)
<100 pg/mL	94	9	9.6	—	42.4 (33.3)
Cholesterol (<150 or >240 mg/dL)	62	37	59.7	151.7 (43.9)	—
<150 mg/dL	62	35	56.5	–	122.7 (16.7)
>240 mg/dL	62	2	3	—	293.5 (54.4)
Unintentional weight loss	61	28	45.9	—	—
BMI (<24 or >40) kg/m^2	97	42	43.3	29.7 (8.4)	—
<24	97	31	32	—	21.3 (1.6)
>40	97	11	11.3	—	45.6 (5.4)
Phosphorus (>5.5 mg/dL)	100	42	42	5.2 (1.5)	6.6 (1.0)
Albumin (<3.8 mg/dL)	99	37	37	3.9 (0.4)	3.5 (0.2)
Lack of appetite	98	37	37	—	—
Interdialytic weight gain (>4%)	99	30	30	—	—
HbA1c (>7%)	44	9	20	6.4 (1.4)	—
Adjusted calcium (<8.4 mg/dL or >10.2 mg/dL)	91		17.6	9.0 (1.0)	—
<8.4 mg/dL	91	11	12.1	—	7.2 (1.8)
>10.2 mg/dL	91	5	5.5	—	10.5 (0.1)
Hospitalized overnight within month	100	10	10	—	—
Wound not healing	99	6	6	—	—
Infection	99	6	6	—	—
Potassium (>6 mEq/L)	94	3	3.2	4.8 (0.7)	6.6 (0.8)

BMI, body mass index; HbA1c, glycated hemoglobin A1c; PTH, serum intact parathyroid hormone; SD, standard deviation.
*Prevalence among those with available data.

Table 4. Renal-Modified NCP Chains for Risk Factors With Prevalence at Least 30%

Risk Factor (Prevalence*)	Diagnosis Group (Frequency†)	Etiology Group (Frequency†)	Intervention Group (Frequency†)	Assessments Recommended for Monitoring and Evaluation
Albumin <3.8 mg/dL (37%)	Insufficient protein‡ (73%)	Insufficient intake‡ (93%)	Education in basic concepts (68%)	Albumin, BUN, protein intake, SGA score
PTH >300 pg/mL (63%)	High PTH‡ (44%)	Nonoptimized treatment‡ (81%)	Health care team consult‡ (76%)	PTH
Cholesterol <150 mg/dL (56%)	Insufficient energy (60%)	Insufficient intake‡ (67%)	Education in basic concepts (50%)	Weight trend, SGA score, energy intake
Unintentional weight loss (46%)	Insufficient energy (64%)	Insufficient intake‡ (78%)	Recommend specific foods‡ (79%)	Weight trend, SGA score, energy intake
BMI <24 kg/m^2 (32%)	Insufficient energy‡ (68%)	Insufficient intake‡ (90%)	Education in basic concepts (63%)	Weight trend, SGA score, energy intake
Phosphorous >5.5 mg/dL (42%)	High phosphorus‡ (79%)	Nonoptimized treatment‡ (94%)	Education in basic concepts (81%)	Serum phosphorous, phosphorous intake
Poor appetite (37%)	Insufficient energy‡ (68%)	Insufficient intake‡ (84%)	Recommend specific foods‡ (81%)	Weight trend, SGA score, energy intake
Interdialytic weight gain >4% (30%)	Excessive IDWG‡ (73%)	Excessive intake‡ (100%)	Education in basic concepts (82%)	Weight trends

BMI, body mass index; BUN, predialysis blood urea nitrogen; IDWG, interdialytic weight gain; NCP, Nutrition Care Process; PTH, serum intact parathyroid hormone; SGA, subjective global assessment.

*Percent of patients, of those with available data, with the screening parameter in the specified "at risk" range.

†Percentage of patients with a diagnosis in this group selected of those for whom the option selected at the previous step was the same.

‡$P < .05$ for being selected more frequently than other options at the same step by χ^2 test.

patterns (by χ^2 test with $P < .05$) for at least 1 step; the remaining 6 risk factors with less than 30% prevalence did not.

Figure 3 presents the OR, indicating the relative likelihood of each assessment being completed after selecting a diagnosis in the related group at the previous visit compared with those for whom a diagnosis in that group was not selected. Only significant ($P < .05$) OR are included in the figure, the greatest of which was the likelihood of a patient's protein intake being assessed after a diagnosis in the insufficient protein group was made (OR = 4.08, $P < .05$).

Table 5 presents the analysis of changes in outcome parameters over the course of the study for each of the most commonly identified diagnosis groups. Among patients with a diagnosis in the insufficient protein group who had measures at both time points ($n = 38$), protein intake increased by a mean of 0.11 g/kg/day ($P = .022$). Among patients diagnosed within the high PTH group, PTH decreased by a mean 176.85 pg/mL ($n = 19$, $P = .011$). Among patients diagnosed within the high phosphorous group, serum phosphorous decreased by a mean of 0.91 mg/dL ($n = 33$, $P = .006$), whereas mean phosphorous intake increased by 157.27 mg/day ($n = 16$, $P = .022$).

Discussion

This study demonstrates the clinical utility of a web-based HD-specific nutrition algorithm. This utility includes the ability to track changes in assessment measures over time. Feasibility was demonstrated by conducting this study in variety of HD centers both in the United States and internationally.

Clinical Utility

The algorithm was successful in identifying risk factors in a majority of patients (aim 1a), and a significant trend was observed for patients with a greater number of risk factors to have diminished serum albumin concentrations. Considering the evidence that malnutrition and inflammation are predictors of morbidity and mortality in HD patients[3]; this relationship provides support for the ability of the algorithm to identify objective nutritional risk (aim 1b). In addition to identifying patients at nutritional risk, the nonrandom selection patterns at each step serve as evidence that the algorithm was successful in facilitating logical clinical practice decisions rather than arbitrary selections (aim 1c).

Capturing Patient Outcomes

In addition to identifying risk and guiding logical practice, the algorithm was able to guide practice decisions that were relevant and appropriate. First, we observed that a patient who received a particular diagnosis at the first visit would be more likely to have related measures assessed at the follow-up visit (aim 2a, Fig. 2) including a greater than fourfold increased likelihood that protein intake would be assessed to monitor a diagnosis within the insufficient protein diagnosis group. Some measures, including albumin, SGA score, and weight trend, did not demonstrate a significant change in likelihood of assessment. However,

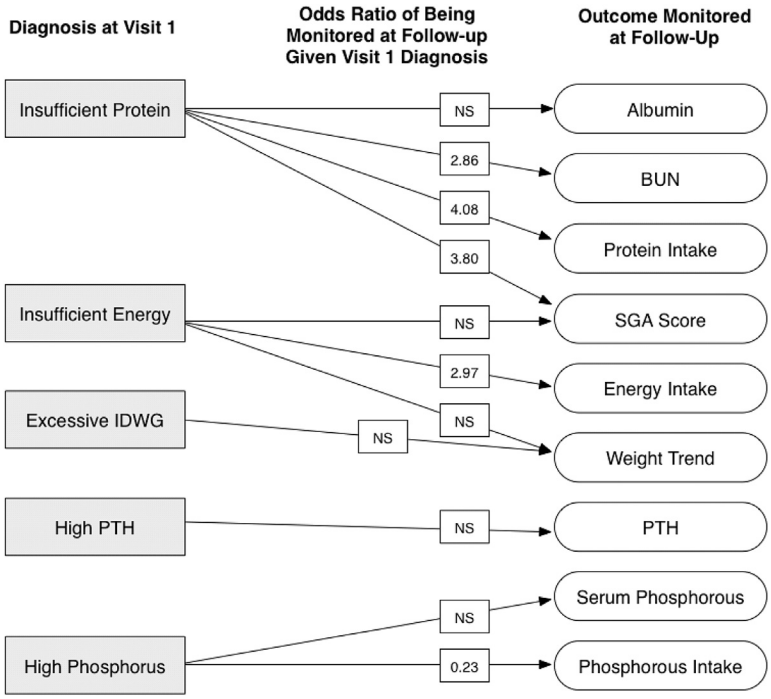

Figure 3. Links between diagnoses at the first visit and risk factors monitored at follow-up odds ratios for likelihood of outcomes being assessed during the 3-month follow-up visit after related nutrition problems were diagnosed at the initial visit are listed for those with $P < .05$. NS–not significant ($P \geq .05$). BUN, blood urea nitrogen; IDWG, interdialytic weight gain; PTH, parathyroid hormone; SGA, Subjective Global Assessment.

these measures are routinely assessed in most HD patients, and thus a significant increase in likelihood was not possible. Additionally, the decrease in likelihood of assessment of phosphorous intake after a diagnosis within the high phosphorous group may at first seem paradoxical, but inspection of the related NCP chains reveals it to be further evidence of logical practice patterns. In Table 4, it can be seen that for 94% of high phosphorous diagnosis group, the dietitian determined the etiology to be nonoptimized treatment (e.g., insufficient vitamin D3/D2). Therefore, because diet had been ruled out as an underlying cause of the problem, it would be logical and appropriate to avoid repeating the time consuming dietary assessment at subsequent visits.

For our final aim, the ability of the algorithm to capture changes in outcomes related to identified diagnoses were evaluated. The algorithm captured significant increase in protein intake in patients with insufficient protein diagnoses, a significant decrease in PTH for diagnoses in the high PTH diagnostic group, and both a significant decrease in serum phosphorous and a significant increase in phosphorous intake for diagnoses in the high phosphorous group.

The scope of this project is insufficient to draw conclusions about the impact of the algorithm on frequency and

Table 5. Changes in Outcomes Relevant to Most Commonly Selected Diagnosis Groups

Diagnosis Group*	Related Outcome	*N*	Baseline Mean (SD)	3-Month Mean (SD)	*P*†
Insufficient protein	Serum albumin	48	3.80 (0.36)	3.79 (0.38)	.863
	BUN	28	45.27 (17.55)	44.50 (15.47)	.789
	Protein intake (g/kg/d)	38	0.79 (0.31)	0.90 (0.38)	**.022**
	SGA score	33	5.07 (1.42)	5.26 (1.27)	.423‡
Insufficient energy	SGA score	36	5.46 (1.49)	5.34 (1.30)	.840‡
	Energy intake (kcal/kg/d)	43	24.46 (10.68)	24.76 (10.96)	.798
	Current weight	50	79.09 (27.25)	78.89 (27.36)	.541
Excessive IDWG	Current weight	24	90.36 (34.07)	89.90 (32.99)	.609
High PTH	PTH	19	797.04 (545.20)	620.19 (139.57)	**.011**
High phosphorous	Serum phosphorous	33	6.69 (0.97)	5.78 (1.71)	**.006**‡
	Phosphorous intake	16	1,044.93 (270.84)	1,202.20 (330.80)	**.022**

BUN, blood urea nitrogen; IDWG, interdialytic weight gain; PTH, parathyroid hormone; SD, standard deviation; SGA, subjective global assessment.

*Terms used are labels for diagnosis groups (note individual terms) that include data from patients assigned any of several closely related nutrition diagnoses.

†*P* value for difference from baseline to 3 months for each outcome via paired *t*-test unless otherwise specified; significant differences in bold.

‡Wilcoxon signed rank test.

magnitude of improvements, and further study is needed to address this question. However, it has been demonstrated that the algorithm was able to capture both improvements and regressions in clinically relevant factors.

Other Algorithms in Nutrition Practice

In nondialysis populations, studies have shown benefits in nutrition-related process and outcome measures when algorithms were used. Adam and Batson[21] identified interventions likely to improve delivery of enteral feed and manage or eliminate problems with enteral feeds, an example of an improved process measure when using an algorithm. In a randomized control trial by Woien and Bjok,[22] which investigated a feeding algorithm in intensive care patients, they indicated that the nutrition assessment algorithm had a significant effect on prescribing and delivering the nutrition plan; its use obtained target levels rapidly and resulted in an improvement of nutritional care.

Finally, a multicenter cluster-randomized clinical trial by Martin et al[23] validated a nutrition algorithm and its implementation process for intensive care unit patients. The use of the algorithm resulted in a significant improvement in clinical outcomes but the dietitians in the intervention group reported approximately 30% increase in time allocated to intensive care patients, whereas numerous dietitians at the control hospital reported having only enough time to collect data.[23]

A systematic approach to nutrition care for HD patients was investigated by Campbell et al,[24] in a retrospective analysis. Following the implementation of a protocol where dietitians conducted dietary interviews every 6 months and monitored weight and biochemistries monthly, data were gathered on 65 HD patients in energy and protein intake, nutritional status, weight, and biochemical parameters. Results of this study showed a reduction in the percent of patients with Protein Energy Wasting as measured by the SGA (14%-3%) and a significant reduction in serum phosphorus.[24]

Renal-Modified NCP Usage

Additionally this work is an illustration of the dynamic and changing nature of the NCP and International Dietetics and Nutrition Terminology. Since the development of the algorithm, 2 new editions of the IDNT manual have been released, with a fifth edition expected in mid-2014. With each edition, new terms are defined at each step. Of particular note in relation to this algorithm, the second edition the interventions have been expanded, and physical examination findings have been added as assessments. It is important that any algorithm evolves with the IDNT, so that the terminology is up-to-date to for standardization and comparison.

Practical Application

With increasing numbers of CKD patients and high dietitian case loads, a nutrition algorithm, which provides dietitians with a decision making framework to conduct nutrition care could be beneficial in improving outcomes such as serum phosphorus, serum albumin, weight status, and lipid abnormalities. Further studies can and should be done with this algorithm to test specific interventions for key nutrition problems. In a small survey of dietitians participating in the study, we found that 1 barrier to widespread use of this tool is the additional time reported for patient interaction and entering the information into the algorithm.[25] However, more than two-thirds of the dietitians were neutral or felt that the algorithm was easy to use and flowed logically, and the majority felt that the algorithm improved the quality of care and interactions with the patients.[25]

Other algorithms used to guide care in other settings have showed improved patient outcomes, and, given the complexity of the nutritional management of HD patients and growing CKD population, having clinical decision support to guide the dietitian through the nutritional management of these patients is important. This study has demonstrated the clinical utility of such a tool as well as its ability to collect data on practice patterns and outcomes, but further research is needed into the impact of the use of the tool on patient outcomes and its ability to test and aid the development of clinical practice guidelines.

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