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Preoperative Nutritional Risk Assessment in Predicting Postoperative Outcome in Patients Undergoing Major Surgery

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Abstract
Introduction: Although a variety of nutritional indices have been found to be valuable in predicting patient outcome when used alone, there is no consensus on the best method for assessing the nutritional status of hospitalized patients. Therefore, the aim of this study was to assess the nutritional status of a cohort of patients who underwent major elective surgery using the Nutritional Risk Index (NRI), Maastricht Index (MI), Subjective Global Assessment (SGA), and Mini Nutritional Assessment (MNA) to determine the best possible nutrition screening system in surgical practice.
Methods: The study population consisted of 460 patients who underwent major elective surgery between December 1999 and March 2002. Each patient had a complete set of the three nutritional assessment techniques (NRI, MI, SGA); in addition, the MNA was performed in patients older than 59 years of age. One of the coauthors who was unaware of the nutritional assessments assessed the patients for postoperative morbidity and mortality. Complications were classified as major or minor and as infectious or noninfectious. To assess the predictive value of the assessment techniques, likelihood ratios were calculated for the various strata of each method. The odds ratio and receiver operating characteristic (ROC) curves were also calculated to describe and compare the diagnostic value of each of the four nutrition indices.
Results: Twenty patients died during the study period. No complications occurred in 329 of the 460 patients; 42 patients suffered from two or more complications. The frequency of malnutrition was found to be 58.3%, 63.5%, and 67.4% as assessed by the SGA, NRI, and MI, respectively. Morbidity rates, especially severe infectious and noninfectious complications, were significantly higher in malnourished patients in all nutritional indices. The likelihood ratio was well correlated with the risk categories of every nutritional index. The area under the ROC curves revealed that each scoring system proved to be significantly powerful in predicting the morbidity (infectious and noninfectious severe morbidity) and mortality. However, no differences were detected among the nutritional indices in 460 patients. The odds ratio for morbidity between the well nourished and malnourished patients was 3.09 [95% confidence interval (CI), 1.96–4.88], 3.47 (95% CI, 2.12–5.68), 2.30 (95% CI, 1.43–3.71), and 2.81 (95% CI, 0.79–9.95) for the SGA, NRI, MI, and

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MNA, respectively. All indices except the MNA were significantly predictive for morbidity. The odds ratios were not statistically different among the indices.
Conclusions: Our findings revealed that all nutritional assessment techniques can be safely applied to the clinical setting with no significant difference in predictive value. We therefore strongly recommend the use of any of these techniques to improve the outcome of surgical care. Meanwhile, further investigations are needed, and much effort must be given to find the best method for assessing nutritional status.

Protein energy malnutrition remains a major health concern. Approximately one-third to one-half of hospitalized patients is malnourished at the time of admission.[1] This clinical problem tends to be worse in patients attending surgical clinics. In fact, nutritional depletion not only can adversely affect a surgical patient's clinical condition[2,3] it may increase his or her risk of a poor postoperative outcome,[4–7] thereby increasing health care costs for both patients and health insurance companies. It is therefore vital to detect and treat malnutrition in patients before they undergo major surgery.

Numerous researchers have sought a reliable, valid scoring system that can identify patients with poor nutritional status at the time of admission. Traditionally, scoring systems have been based on objective measurements of nutritional status such as oral energy intake, body weight, weight loss, anthropometric data, total lymphocyte count, body composition analysis, creatinine–height index, hepatic secretory proteins, and cell-mediated immunity. However, individual measurements of these objective parameters are not powerful enough to detect malnourished patients at high risk. The absence of a single gold standard objective measure has led investigators to develop various nutritional indices that can be used to stratify patients at increased risk for poor outcomes.[8,9] These prognostic indices include the Nutritional Risk Index (NRI)[10,11] and the Maastricht Index (MI),[12] which are based on mathematical equations, and the Subjective Global Assessment (SGA)[13,14] and Mini Nutritional Assessment (MNA),[15,16] which are based on clinical and subjective assessments.[5]

All four of the nutritional scoring systems have been found to be valuable for predicting patient outcome when used alone. However, there is no consensus on the best method for assessing the nutritional status of hospitalized patients. Hence, our goals were to assess prospectively, using the NRI, MI, SGA, and MNA scoring systems, the nutritional status of a cohort of patients scheduled for major surgery and to determine postoperative morbidity and mortality.

PATIENTS AND METHODS

Patients

This prospective trial was conducted in our hospital's department of surgery. Our Ethical Committee approved the study, and informed consent was obtained from all patients. Patients who were scheduled for elective major surgery between December 1999 and March 2002 and who were 18 years and older at the time of surgery were eligible. Major elective surgery was defined as oncologic resection for gastrointestinal, thoracic, or urologic malignancy, solid organ resection, stoma closure with resection and anastomosis via a median laparotomy, noncardiac major peripheral vascular procedures, and major amputations (above-knee amputations).

Patients were excluded if they were expected to die of their primary disease within 6 months or if they died during surgery, if they had received preoperative parenteral nutrition or were taking immunosuppressive and/or anticoagulant drugs, or if they had undergone an operation during the preceding year or exploratory laparotomy because of advanced tumors. Patients were also excluded if they did not accept the planned major surgery, they had a known chronic disabling disease that required nursing help, could not participate in interviews, were lost to follow-up, or were pregnant or nursing at the time of the study. All remaining patients were considered potentially eligible.

Study Protocol

On admission, each patient was assessed with the NRI, MI, and SGA. The MNA, which is specifically designed to detect malnutrition in the elderly, was performed only in patients older than 59 years (the life expectance in Turkey is 66.2 years for men and 68.2 years for women). All nutritional assessments were done within 48 hours of admission. No single nutritional index was considered a standard reference. The nutritional assessments were performed by a resident or dietitian and before any treatment regimen or nutritional support was provided.

The NRI is based on serum albumin concentrations and the ratio of present/usual weight, which are used in the following equation.

$$(1.489 \times \text{serum albumin, g/L}) + (41.7 \times \text{present weight/usual weight})$$

The NRI is scored as follows: > 100 indicates that the patient is not malnourished; 97.5 to 100 indicates mild malnourishment; 83.5 to 97.5 indicates moderate malnourishment; and < 83.5 indicates severe malnourishment. The usual weight was defined as the stable weight 6 months or more before admission or before illness. The present weight was determined with a calibrated balance.

The MI is based on serum albumin and prealbumin concentrations, the blood lymphocyte count, and the percentage of ideal weight, which are used in the following equation.

$$20.68 - 0.24 \times \text{albumin}\,(\text{g/L}) - 19.21 \times \text{prealbumin}\,(\text{g/L}) - 1.86 \times \text{lymphocytes}\backslash(10^9/\text{L}) - 0.04 \times \text{percentage ideal weight}$$

Although this index is conventionally called the Nutritional Index, we used the term MI to avoid confusion with the NRI. Patients with an MI > 0 are considered malnourished. The patients' ideal weight was derived from the tables of the Metropolitan Life Insurance Company.

During the SGA, a dietitian evaluated the patients' height and weight (current, before illness, and weight range during the previous 6 months) and took a nutritional history (appetite, intake, gastrointestinal symptoms). In addition, the dietitian evaluated their physical appearance (subjective assessment of fat loss, muscle wasting, edema, and ascites) and noted any existing medical conditions (e.g., encephalopathy, infection, renal insufficiency). Based on this evaluation, the patients were classified as being well nourished (SGA A), moderately malnourished (SGA B), or severely malnourished (SGA C).

The MNA is composed of 18 items, including anthropometric measurements: weight; height; body mass index (BMI) = weight (kg)/size (m^2); weight loss; a global assessment (six questions related to life style, medications, mobility); a dietary questionnaire (eight questions related to the number of meals, food and fluid intake); and a subjective assessment (self-perception of health and nutrition). The maximum score is 30 points; the risk for malnutrition increases as the score decreases. We used the MNA in patients more than 59 years of age. The MNA is scored as follows: 24 to 30, well nourished; 17.0 to 23.5, at risk for malnutrition; and < 17, malnourished. After all of the indices had been assessed, patients were considered well nourished if they achieved the following ratings: SGA A, MI $\leq$ 0, NRI >100, and MNA $\geq$ 24. Otherwise, they were considered malnourished.

Weight was measured to the nearest 0.1 kg and height and circumference to the nearest 0.1 cm. All anthropometric measurements were done at least twice by the same investigator, and the reported values are the means of the repeated measurements.

Blood samples were taken from a cubital vein on admission and included liver and renal function tests, serum electrolytes, lipids and triglycerides, serum protein, albumin, prealbumin, prothrombin time, blood urea nitrogen, creatinine, calcium, inorganic phosphorus, cholesterol and triglycerides, total lymphocyte count (TLC), and hemoglobin. Laboratory data were measured using established standard laboratory methods. Albumin was measured by photometry on a BM/Hitachi 747 automatic analyzer (Beckman-Coulter Synchron LX20 Clinical System; Beckman-Coulter, Fullerton, CA, USA), prealbumin by immunonephelometry (Beckman-Coulter Immage Chemistry Immunochemistry System), and the TLC with an automatic blood cell counter (LH750; Beckman Coulter, Miami, FL, USA). The following values were considered as the reference ranges for our laboratory: albumin, 3.4 to 4.8 g/dl; prealbumin, 0.2 to 0.4 g/L; TLC > 1.5×10^9/L.

The following patient data were recorded: principal diagnosis, coexisting illness, medications, type of scheduled operation (digestive, urologic, noncardiac thoracic, vascular), recent biochemistry, length of stay (LOS) in the intensive care unit (ICU) and in hospital, platelets, complications, and postoperative outcome.

No patient received preoperative nutritional support. The need for postoperative nutritional support was determined by the patient's physician. Such nutrition therapy was provided based on the physicians' concern for the clinical condition of the patient. None of the physicians was aware of their patient's nutritional score, and they were blinded to the nutritional evaluation. When provided, parenteral nutrition (PN) was given as a continuous infusion via a central or a peripheral vein depending on the osmolarity of the solution. The PN mixture contained glutamine-free crystalline L-amino acids, carbohydrate (10–20% dextrose, 10% or 20% fat emulsion; 1.1 or 2.0 kcal/ml), vitamins, and minerals. Crystalline amino acids were provided at a calorie/nitrogen ratio of 100 to 150 kcal/1 g of nitrogen. The patients' basal energy expenditure was calculated using the

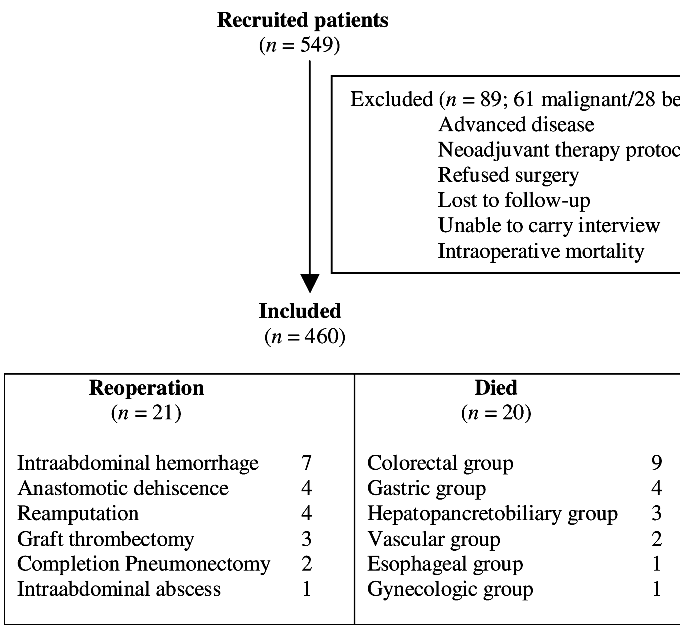

Figure 1. Flow diagram of the present study.

Schofield[17] formula, and the total energy expenditure was estimated by including an additional stress factor and activity factor based on the patient's clinical condition. The dose was increased for 72 hours to a daily caloric goal of 1000 kcal above the resting metabolic expenditure. Vitamins and trace elements (mix) were provided daily, and electrolytes were provided as clinically indicated.

The patients receiving PN were permitted to have oral intake depending on the clinical findings, and the oral intake was recorded. The amount of macronutrient (carbohydrates, lipids, proteins) intake derived from enteral nutrition, PN, and intravenous crystalloid infusions were recorded each day by the nurses and dietitians.

Complications and Outcomes

One of the coauthors assessed the patients for postoperative complications in the hospital until discharge or death and up to 30 days after an operation following successful discharge. Each patient was contacted on postoperative day 30 to further assess morbidity and mortality. This assessor had not seen the patients preoperatively and was unaware of the nutritional assessments. Death was defined as that occurring up to 30 days postoperatively or before discharge if the patient was still in the hospital at 30 days. All complications were classified as major or minor and as infectious or noninfectious. The definitions of outcomes are given in Appendix I.

Statistical Analysis

Differences between the groups for categorical data were analyzed using the chi-squared test or Fisher's exact test, as appropriate. The patients' median age, BMI, time to return to normal activities, length of hospital stay, prealbumin and albumin levels, and TLC were compared using the Mann-Whitney U-test. To assess the predictive value of the methods, likelihood ratios were calculated for the various strata of each method.[18] In addition, the odds ratio and its 95% CI were calculated. Receiver operating characteristic (ROC) curves were used to describe and compare the performance of diagnostic values of the four nutrition indices. The areas under the ROC curves and 95% CIs for all variables were calculated as described by Hanley and McNeil.[19,20] We assessed whether the difference in the areas under two curves was random or real by calculating a critical ratio z (AccuROC for Windows, version 2.5; Accumetric, Montreal, Quebec, Canada). Values of $P < 0.05$ were considered statistically significant. Statistical analyses were done with SPSS (version 11.5) where appropriate.

RESULTS

Demographics

For the study, we recruited 549 patients who underwent major surgery at our institution. Figure 1 documents the exclusions (n = 89), reoperations (n = 21), and mortality

Table 1.
Demographic characteristics of the 460 participants

Age (years), mean ± SD/median (IQR)	55.31 ± 14.88/57(23)
No. of patients age ≥ 60 years	207 (45%)
Sex (M/F)	265/195
Body mass index (kg/m^2), mean (SD)/median (IQR)	24.35 (4.13)/24.16 (4.14)
Prealbumin (g/L), mean (SD)/median (IQR)	0.19 (0.088)/0.19 (0.13)
Albumin (g/dl), mean (SD)/median (IQR)	3.66 (0.63)/3.80 (0.90)
Lymphocyte ($\times 10^9$/L), mean (SD)/median (IQR)	1.81 (0.79)/1.80 (1.10)
Diagnosis	
Cancer	293 (63.7%)
GI cancer	229 (49.8%)
Lung cancer	30 (6.5%)
Urologic cancer	12 (2.6%)
Other cancer	22 (4.8%)
Benign	167 (36.3%)
GI tract	67 (14.6%)
Vascular	45 (9.8%)
Adrenal	7 (1.5%)
Respiratory	18 (3.9%)
Other	30 (6.5%)
No. of patients with coexisting illness	113 (24.6%)
No. of curative surgery for cancer	258 (88.1%)/293 patients
No. of patients with GI surgery	296 (64.3%)
No. of patients with postoperative nutritional support > 5 days	43 (9.8%)
Time to return normal activities (days), mean (SD)/median (IQR)	8.05 (10.73)/6.00 (5.0)
Length of hospital stay (days), mean (SD)/median (IQR)	19.52 (13.40)/16.0 (12.0)

IQR: interquartile range; GI: gastrointestinal; SD: Standard deviation.

Table 2.
Curative and noncurative surgical data by organ system

Diagnosis	Malignant (no. with curative surgery)	Benign	Total
Esophagus	8(8)	1	9
Gastric	69(58)	15	84
Colorectal	123(109)	24	147
Hepatopancreatobiliary	29(26)	27	56
Adrenal	3(3)	7	10
Respiratory tract	30(27)	18	48
Urinary tract	12(11)	4	16
Gynecologic	17(14)	2	19
Vascular	—	45	45
Spleen	2(2)	24	26
Total	293 (258)	167	460

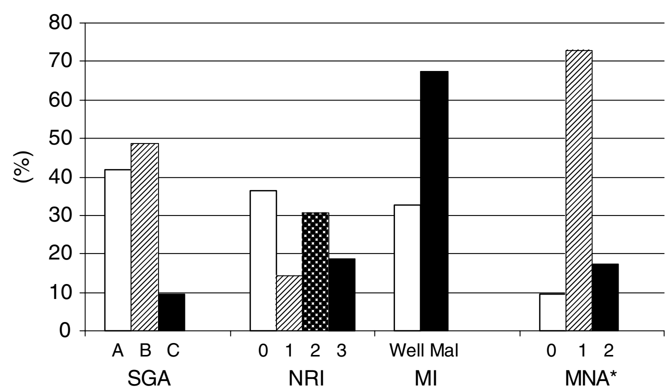

Figure 2. Frequency of malnutrition with various scoring techniques. SGA: Subjective Global Assessment; NRI: Nutritional Risk Index; MI: Maastricht Index; MNA: Mini Nutritional Assessment. *The MNA was performed on 207 patients.

(n = 20). Data from the 460 patients who were included were analyzed. Table 1 lists the patients' demographic characteristics; BMI; preoperative prealbumin, albumin, and lymphocyte levels; diagnoses; patients with coexisting illness; patients who underwent curative surgery for cancer and gastrointestinal (GI) surgery; patients who were given postoperative nutritional support; LOS; and time to return to normal activities.

The surgical procedures are detailed in Table 2, which groups the patients by the organ system affected. Of the 460 patients, 258 underwent curative resection for 293 malignant disorders. All 460 patients were assessed with the NRI, MI, and SGA nutritional indices; 207 patients were older than 59 years and thus were assessed with the MNA as well. The frequency of malnutrition in our patient population was 58.3%, 63.5%, and 67.4% as

Table 3.
The comparison of survivors and nonsurvivors

Parameter	Non survivors (n = 20)	Survivor (n = 440)	*P*
Gender (M/F)	11/9	254/186	0.809
Age (years), mean (SD)/median (IQR)	58.75 (9.87)/58.50 (17.75)	55.15 (15.06)/57.0 (23.0)	0.412
BMI (kg/m^2), mean (SD)/median (IQR)	23.29 (4.53)/22.56 (3.41)	24.40 (4.11)/24.17 (4.14)	0.162
Prealbumin (g/L), mean(SD)/median (IQR)	0.16 (0.12)/0.12 (0.14)	0.19 (0.09)/0.19 (0.13)	0.027
Albumin (g/dl), mean (SD) / median (IQR)	3.01 (0.63)/3.13 (1.10)	3.69 (0.61)/3.80 (0.80)	<0.001
Lymphocyte ($\times 10^9$/L), mean (SD)/median (IQR)	1.31 (0.48)/1.25 (0.68)	1.84 (0.79)/1.80 (1.20)	0.003
SGA score (no.)			0.121
Well nourished	5 (2.6%)	187 (97.4%)	
Malnourished	15 (5.6%)	253 (94.4%)	
NRI score (no.)			0.001
Well nourished	0	168 (100%)	
Malnourished	20 (6.8%)	272 (93.2%)	
MI score (no.)			0.007
Well nourished	1 (0.7%)	149 (99.3%)	
Malnourished	19 (6.1%)	291 (93.9%)	
No. of GI surgery	17 (5.7%)	279 (94.3%)	0.049
No. of cancer patients	17 (5.8%)	276 (94.2%)	0.043
No. of curative cancer surgery[a]	14 (5.4%)	244 (94.6%)	0.439
No. of coexisting illness	11 (9.7%)	102 (90.3%)	0.003
No. of vascular patients	2 (4.4%)	43 (95.6%)	1.000

[a]The number of cancer patients is 293.

assessed by the SGA, NRI, and MI indices, respectively. The severity of malnutrition was unequally distributed between the indices. Most of the malnourished patients were considered to have mild malnourishment with the SGA index, whereas the same cases were rated as having moderate or severe malnourishment with the NRI (Fig. 2).

Mortality and Morbidity

Twenty patients died during the study period. The causes of mortality in the colorectal surgery group were stratified as follows: three with pulmonary complications, two with myocardial infarction, two with anastomotic dehiscence, one with a cerebrovascular accident, and one with intraabdominal hemorrhage. In the gastric surgery group, the distribution was as follows: two pulmonary complications, one anastomotic dehiscence, and one myocardial infarction. In the hepatopancreatobiliary surgery group, two patients died of intraabdominal hemorrhage and one of intraabdominal sepsis. Among the vascular surgery cases, two patients died of pulmonary complications, one of which was due to pulmonary infection and the other to pulmonary embolus. One patient died from septic complications following esophageal surgery. Finally, one patient died of pulmonary complications following gynecologic surgery. Data for the patients who died during the study (n = 20) and those who survived (n = 440) are presented in Table 3.

No complications occurred in 329 of the 460 patients; and 42 patients experienced two or more complications. The list of complications is presented in Table 4. The distribution of complications (infectious and noninfectious) between the well nourished and malnourished patients for each scoring system is shown in Table 5. The number of complications was higher in the malnourished patients in all four of the nutritional indices. When the relation of mortality and morbidity with the given disease was considered, the data revealed that the presence of GI disorders significantly increased the number of complications, whereas the presence of cancer failed to reach statistical significance. Additionally, the presence of GI disorders, cancer, and coexisting illness significantly correlated with mortality. No such relation for either morbidity or mortality was observed in the presence of vascular disorders (Table 6).

Table 5 shows the association between the severity of malnutrition, diagnoses, and morbidity and mortality according to the NRI, MI, and SGA indices. The malnourished patients were significantly older than the well nourished patients for all three nutritional indexes. The severity of malnutrition varied in relation to the diagnosis. Significantly more gastric and cancer patients were

Table 4.
The list of postoperative infectious and non-infectious (severe and non-severe) complications

Infectious/severe complications	
Pneumonia	10
Intraabdominal abscess	9
Anastomotic leakage	7
Septicemia	7
Surgical site infection (deep)/wound dehiscence	3
Enterocutaneous fistula	2
Pancreatic fistula	1
Gastrostomy catheter leakage	1
Infectious/nonsevere complications	
Surgical site infection	57
Urinary infection	4
Cholecystitis	1
Laryngitis	1
Sinusitis	1
Noninfectious/severe complications	
Respiratory failure	14
Deep hemorrhage	9
Hypotension	6
Pulmonary embolus	6
Pyrexia of unknown origin	5
Cardiac failure	3
Arrhythmia	3
Deep venous thrombosis	3
Graft thrombosis (arterial)	3
Cardiac infarct	2
Cerebrovascular accident	2
Wound dehiscence (deep)	2
Ureterohydronephrosis	2
Gastrointestinal hemorrhage	1
Noninfectious/nonsevere complications	
A telectasis	7
Wound dehiscence (superficial)	6
Impaired renal function	5
Gastric atony	2
Anastomatic stricture	1
Superficial hemorrhage	1
Thrombophlebitis	1

malnourished than patients who had nongastric or benign disorders. There were no significant differences in outcome regarding the presence of vascular disease when we compared the well nourished and malnourished patients using all three scoring systems. Patients with severe malnutrition had significantly higher complication rates. Morbidity rates, especially for severe infectious and noninfectious complications, were significantly higher in the malnourished patients. A statistically significant difference in mortality was found between the well nourished and malnourished patients with the NRI and MI indices but not with the SGA. Moreover, time to return to normal activities and LOS were significantly longer in the malnourished patients according to all three indices (Table 5).

Postoperative Outcome

Table 7 explains the role of the NRI, MI, and SGA indices in predicting the postoperative outcome at admission. The likelihood ratio was well correlated with the risk categories for all three nutritional indices. The area under the ROC curve revealed that each scoring system was significantly powerful for predicting morbidity (infectious and noninfectious severe morbidity) and mortality. However, no differences were detected among the three nutritional indices in the 460 patients ($P > 0.05$). The role of the MNA index in predicting the postoperative outcome was investigated by reassessing the 207 patients who were older than 59 years using the same statistical analysis. No significant differences were detected among the SGA, NRI, MI, and MNA (data not presented). The odds ratios for morbidity between the well nourished and malnourished patients were 3.09 (95% CI, 1.96–4.88), 3.47 (95% CI, 2.12–5.68), 2.30 (95% CI, 1.43–3.71), and 2.81 (95% CI, 0.79–9.95) for the SGA, NRI, MI, and MNA indices, respectively. All indices except the MNA were significantly predictive for morbidity. The odds ratios were not statistically different among the four indices. Because the number of deaths was small, the odds ratio was not calculated for mortality.

DISCUSSION

Quantifying the risk of death or morbidity related to malnutrition at an early stage during the hospital stay has a crucial impact on surgical practice. However, malnutrition is often unrecognized and not treated properly, which results in poor clinical outcomes. Although there are a number of indices that can be used to assess malnutrition and determine postoperative risk, there is currently no consensus on the best method for assessing the nutritional status of hospitalized patients.[21,22] Therefore the goal of our present study was to determine the best possible prognostic nutritional assessment that can be used to stratify patients at increased risk for a poor surgical outcome. Our results suggest that all four of the indices studied herein (SGA, NRI, MI, MNA) accurately predict the occurrence of morbidity and mortality.

In a study by Detsky *et al.*,[23] five objective measurements (albumin, transferrin, delayed cutaneous hypersensitivity, anthropometry, creatinine–height index) were used together with the SGA and prognostic nutritional index to determine their value in predicting nutritionally associated complications in 59 surgical patients. The SGA was found to be the best nutritional assessment technique, with a sensitivity of 0.82 and specificity of 0.72.[23] However, the Veterans Study[24] investigated the impact of perioperative total PN in surgical patients and found that the NRI was better than the SGA for determining which patients should receive perioperative total PN, although the difference was not statistically significant. The validity of the nutritional assessment techniques was studied in the elderly (≥ 65 years); the SGA was found to be a more useful tool for detecting residents with established malnutrition, whereas the MNA was more effective for detecting residents who required preventive nutritional measures.[25] Van Nes *et al.*[26] used the MNA in 1145 patients and found that a score below 17 was associated with increased in-hospital mortality and a longer LOS. Other researchers have obtained similar findings that support this conclusion.[16,27,28] However, the MNA has been specially designed to evaluate the risk of malnutrition in the elderly.

Naber *et al.*[22] investigated the prevalence of malnutrition and its association with disease complications in 155 nonsurgical hospitalized patients using the SGA, NRI, and MI. Following multivariate analysis, which included the disease category and severity, odds ratios for the development of complications in malnourished compared with well nourished patients during a hospital stay were calculated as follows: 1.7 (95% CI 0.8–3.6) for the SGA, 1.6 (0.7–3.3) for the NRI, and 2.4 (1.1–5.4) for the MI. Although the MI seems to be the most predictive, the malnourished patients showed an increased risk of complications for all three nutritional indices. De Jong *et al.*[12] supported these findings by documenting that the patients could be correctly classified in relation to their nutritional status in 93% of the cases with a sensitivity of 93% and a specificity of 94% using the MI.

The incidence of either severe infectious or noninfectious complications, mortality, time to return to normal activities, and LOS in the malnourished group were significantly higher than those of the well nourished group for all of the nutritional assessment indices in our study. However, the distribution of both infectious and noninfectious, nonsevere complications was similar between the well nourished and the malnourished patients for all four nutritional indices. In addition, the number of patients who had cancer and gastrointestinal disease was significantly higher in the malnourished group in all of the indices. Hence, the disease category was strongly associated with the occurrence of a poor surgical outcome. Others have reported similar findings.[21,22]

The level of malnourishment is directly correlated with both the severity and the frequency of postoperative complications. In the present study, the likelihood ratio revealed that severely malnourished patients were more likely to have a worse surgical outcome. Detsky *et al.*[21] evaluated the nutrition-associated complications in patients undergoing gastrointestinal surgery and found that there was progression of the likelihood ratio (0.66 for SGA A, 0.96 for SGA B, 4.44 for SGA C); they documented that patients who were rated as SGA C had a sevenfold increase in the likelihood of poor postoperative complications. Our likelihood ratio for the SGA was similar to theirs. However, the odds ratios from the present study documented that the increases in postoperative morbidity risks of malnourished patients when compared to those of well nourished matches were 3.09 times in the SGA, 3.47 times in the NRI, 2.03 in the MI, and 2.81 times in the MNA.

Our study design has a few limitations. First, our subjects did not form a homogeneous group. Although they all underwent major elective surgery and all were critically ill, their primary diagnoses varied broadly. Second, the addition of postoperative nutritional support to the management of some patients may have influenced the results. The probable consequences triggered by such a modification were all measured by every nutritional assessment technique, which makes no bias in favor of any index in the comparison. Furthermore, no standard nutritional support regimen was developed to avoid interference between the interpretation of the assessment methods while giving the decision to start or not to start support in an individual patient. Third, although the likelihood ratio was significantly correlated with each nutritional index, it should have been higher than 10 to have diagnostic value. Additionally, although the area under the ROC curves was significantly accurate for morbidity and mortality, the values were not within the perfect accuracy level of 1.0. Nevertheless, this is a single-center study in which all of the nutritional assessment and support were performed by the same trained staff.

CONCLUSIONS

Our findings revealed that nutritional assessment techniques based on mathematic equations or clinical and subjective evaluations can be safely applied to the clinical setting with no significant difference in predictive value. Therefore, we strongly recommend the use of any of these techniques to improve the outcomes of surgical care. Meanwhile, further investigations are needed, and efforts are needed to find the best method of nutritional assessment with the most accuracy.

Table 5.
Association between the severity of malnutrition, diagnoses, morbidity, and mortality according to various nutrition scores

	Subjective Global Assessment		
Charcteristic	Malnourished (n = 268)	Well nourished (n = 192)	*P*
Age (years), mean (SD), median (IQR)	58.9 (14.8), 63 (19)	50.2 (13.5), 51(20)	<0.001
No. of GI patients GIS	198 (73.9%)	98 (51.0%)	<0.001
No. of cancer patients	184 (68.7%)	109 (56.8%)	0.009
No. curative cancer surger[a]	157 (85.3%)	101 (92.7%)	0.061
No. with coexisting illness	80 (29.9%)	33 (17.2%)	0.002
No. of vascular patients	32 (11.9%)	13 (6.8%)	0.066
Morbidity	100 (37.3%)	31(16.1%)	<0.001
Infectious complications			
Severe	33 (12.3%)	7 (3.6%)	0.001
Nonsevere	50 (18.7%)	14 (7.3%)	0.001
NonInfectious complications			
Severe	44 (16.4%)	17 (8.9%)	0.018
Nonsevere	14 (5.2%)	9 (4.7%)	0.795
Mortality	15 (5.6%)	5 (2.6%)	0.121
Time to return to normal activities	mean (SD) 8.91 (9.44), median (IQR) 6.0 (5.0)	6.85 (12.22), 5.0 (4.75)	<0.001
Length of hospital stay, (days)	mean (SD) 20.78 (12.63), median (IQR) 18.0 (14.75)	17.77 (14.27), 15.0 (10.0)	0.001

APPENDIX: DEFINITIONS OF OUTCOMES

- *Abscess (intraperitoneal/extraperitoneal):* requires operative or spontaneous drainage of an abdominal purulent collection.
- *Anastomotic leakage:* discharge of bowel content via a drain, wound, or abnormal orifice.
- *Atelectasis:* confirmed by chest radiography, requiring bronchoscopy.
- *Bronchopleural fistula:* confirmed by chest radiography.
- *Cardiac failure:* symptoms or signs of left ventricular or congestive cardiac failure that require an alteration from preoperative therapeutic measures.
- *Cerebrovascular accident:* development of a new and persistent (> 48 hours) central neurologic deficit.
- *Chest infection:* production of purulent sputum with positive bacteriologic cultures, with or without chest radiographic changes or pyrexia, or consolidation seen on chest radiography.
- *Coexisting disease:* A history of congestive heart failure, myocardial infarction, angina, or cerebrovascular disease was defined as cardiovascular disease. Chronic obstructive lung disease, respiratory insufficiency, or bronchial asthma was defined as respiratory disease. Diabetes mellitus included types I and II. Chronic liver disease documented by either biopsy or by persistently elevated serum transaminases was defined as liver disease. All of the patients with coexisting diseases were self-dependent and were not hospitalized because of these pathologies.
- *Deep hemorrhage:* postoperative bleeding requiring reexploration.
- *Deep venous thrombosis and/or graft thrombosis:* clinical evidence that necessitated full-dose anticoagulation or radiologic documentation.
- *Emphyema:* radiologic changes and documentation of a pathologic organism in the pleural fluid.
- *Gastrointestinal hemorrhage:* gastrointestinal blood loss of sufficient abundance requiring transfusion of two or more units of blood during any 24-hour period for bleeding.
- *Hepatic dysfunction:* a postoperative rise in total serum bilirubin > 2.0 mg/dl above on-study levels (excluded from this complication were patients who underwent pancreatic and biliary tract procedures).
- *Hypotension:* a fall in systolic blood pressure below 90 mmHg for more than 2 hours.
- *Impaired renal function:* an increase in blood urea of > 5 mmol/L from preoperative levels.

Table 5. Continued.

Nutritional Risk Index			Maastricht Index			
Malnourished (n = 292)	Well nourished (n = 168)	P	Malnourished (n = 310)	Well nourished (n = 150)	P	Total
58.2 (15.1) 62 (22)	50.3 (13.0), 52 (18)	<0.001	57.5 (14.7), 60 (21)	50.8 (14.2), 52 (21.25)	<0.001	55.31 (14.88), 57 (23)
217 (74.3%)	79 (47.0%)	<0.001	224 (72.3%)	72 (48.0%)	<0.001	296 (64.3%)
205 (70.2%)	88 (52.4%)	<0.001	217 (70.0%)	76 (50.7%)	<0.001	293 (63.7%)
176 (85.9%)	82 (93.2%)	0.076	191 (88.0%)	67 (88.2%)	0.974	258 (88.1%)
81 (27.7%)	32 (19.0%)	0.037	82 (26.5%)	31 (20.7%)	0.177	113 (24.6%)
29 (9.9%)	16 (9.5%)	0.887	27 (8.7%)	18 (12.0%)	0.265	45 (9.8%)
107 (36.6%)	24 (14.3%)	<0.001	104 (33.5%)	27 (18.0%)	0.001	131 (28.5%)
35 (12.0%)	5 (3.0%)	0.001	36 (11.6%)	4 (2.7%)	0.001	40 (8.7%)
54 (18.5%)	10 (6.0%)	<0.001	52 (16.8%)	12 (8.0%)	0.011	64 (13.9%)
50 (17.1%)	11 (6.5%)	0.001	48 (15.5%)	13 (8.7%)	0.043	61 (13.3%)
16 (5.5%)	7 (4.2%)	0.534	14 (4.5%)	9 (6.0%)	0.494	23 (5.0%)
20 (6.8%)	0 (0.0%)	0.001	19 (6.1%)	1 (0.7%)	0.007	20 (4.3%)
8.61 (9.21), 6.0 (5.0)	7.07 (12.92), 5.0 (4.0)	<0.001	8.31 (8.87), 6.0 (4.0)	7.51 (13.81), 5.0 (4.0)	0.001	8.05 (10.7), 6 (5)
20.74 (12.45), 18.0 (14.75)	17.41 (14.72), 15.0 (9.0)	<0.001	20.36 (12.53), 17.0 (14.25)	17.79 (14.94), 15.5 (10.25)	0.009	19.5 (13.4), 16 (12)

[a]Number of cancer patients is 293.

Table 6.
Diagnosis-related morbidity and mortality

Factor	Morbidity		Mortality	
	No.	P	No.	P
Cancer				
Yes	90 (30.7%)	0159	17 (5.8%)	0.043
No	41 (24.6%)		3 (1.8%)	
Coexisting illness				
Yes	39 (34.5%)	0.102	11 (9.7%)	0.003
No	92 (26.5%)		9 (2.6%)	
GI Disease				
Yes	100 (33.8%)	0.001	17 (5.7%)	0.049
No	31 (18.9%)		3 (1.8%)	
Vascular disease				
Yes	12 (26.7%)	0.777	2 (4.4%)	1.000
No	119 (28.7%)		18 (4.3%)	

- *Infarct:* standard clinical criteria with enzyme and/or appropriate electrocardiographic changes.
- *Persistent air leak:* confirmed on chest radiography, requiring pleurodesis before the pulmonary drainage system was removed.
- *Pulmonary embolus:* when suspected, confirmed radiologically by angiography or ventilation/perfusion scanning.
- *Pyrexia of unknown origin:* any temperature above 37°C for more than 24 hours occurring after the original pyrexia following surgery, for which no obvious cause could be found.
- *Respiratory failure:* shortness of breath requiring urgent ventilator support.
- *Return to normal activity:* patients who can take care of their personal hygiene, can eat without help, and have no limitations when performing daily activities such as walking.
- *Septicemia and bacteremia:* clinical signs of bacteremia (fever ≥ 38.5°C or shaking chill) and at least one positive blood culture.
- *Septic shock:* same as bacteremia with arterial hypotension and/or hypoperfusion requiring pressor agents for hemodynamic maintenance.

Table 7.
Likelihood ratio and area under ROC curve for 460 patients

	Overall morbidity			Mortality			Infectious/severe complications			Noninfectious/severe complications		
	No.	LR	AUC ± SE 95% CI *P*	No.	LR	AUC ± SE 95% CI *P*	No.	LR	AUC ± SE 95% CI *P*	No.	LR	AUC ± SE 95% CI *P*
SGA												
A	31 (16.1%)	0.48	0.669 ± 0.028, 0.613–0.724, < 0.001	5 (2.6%)	0.59	0.687 ± 0.071, 0.547–0.827, 0.005	7 (3.6%)	0.40	0.677 ± 0.044, 0.590–0.764, < 0.001	17 (8.9%)	0.64	0.645 ± 0.042, 0.563–0.726, < 0.001
B	70 (31.3%)	1.14		6 (2.7%)	0.61		22 (9.8%)	1.14		25 (11.2%)	0.82	
C	30 (68.2%)	5.38		9 (20.5%)	5.66		11 (25.0%)	3.50		19 (43.2%)	4.97	
NRI												
0	24 (14.3%)	0.42	0.659 ± 0.029, 0.603–0.715, < 0.001	0	0	0.797 ± 0.042, 0.714–0.880, < 0.001	5 (3.0%)	0.32	0.687 ± 0.044, 0.602–0.772, < 0.001	11 (6.5%)	0.46	0.657 ± 0.039, 0.580–0.733, < 0.001
1	19 (29.2%)	1.04		2 (3.1%)	0.70		5 (7.7%)	0.88		7 (10.8%)	0.79	
2	49 (34.8%)	1.34		8 (5.7%)	1.32		17 (12.1%)	1.44		22 (15.6%)	1.21	
3	39 (45.3%)	2.08		10 (11.6%)	2.89		13 (15.1%)	1.87		21 (24.4%)	2.11	
MI												
+	27 (18.0%)	0.55	0.671 ± 0.029, 0.615–0.728, < 0.001	1 (0.7%)	0.15	0.743 ± 0.052, 0.640–0.845, < 0.001	4 (2.7%)	0.29	0.695 ± 0.043, 0.611–0.799, < 0.001	13 (8.7%)	0.62	0.651 ± 0.039, 0.575–0.728, < 0.001
–	104 (33.5%)	1.27		19 (6.1%)	1.44		36 (11.6%)	1.38		48 (15.5%)	1.20	

LR: likelihood ratio; AUC: area under the curve; SE: standard error; CI: confidence interval.

- *Superficial and deep surgical site infection (SSI):* Superficial SSI was defined as an infection involving only the skin and the subcutaneous tissue within 30 days of surgery, whereas deep SSI was defined as an infection involving fasciae and muscular layers. SSI was defined either based on clinical criteria (as a purulent wound discharge, a wound that was opened for treatment of presumed infection, a wound breakdown/dehiscence with clinical evidence of infection) or on bacteriologic criteria (a positive culture from a serous or sanguineous discharge).
- *Urinary extravasation/ureterohydronephrosis:* requires radiologic confirmation and/or urine drainage from the drainage catheter.
- *Urinary infection:* the presence of > 10^5 bacteria/ml with the presence of white blood cells in urine that was previously clear.
- *Wound dehiscence:* superficial or deep wound breakdown.
- *Wound hemorrhage:* local hematoma requiring drainage.

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