Impact of nutritional screening index on perioperative morbidity after colorectal cancer surgery as a independent predictive factor

Yoon Hyung Kang¹, Ji Won Park^{1,2,3}, Seung Bum Ryoo¹, Seung Yong Jeong^{1,2,3}, Kyu Joo Park^{1,3}

¹Department of Surgery, Seoul National University Hospital and College of Medicine, Seoul;

²Cancer Research Institute, Seoul National University, Seoul;

³Colorectal Cancer Center, Seoul National University Cancer Hospital, Seoul National University College of Medicine, Seoul, Korea

Purpose: Nutrition status is an important factor for perioperative morbidity in cancer surgery. The aim of this study was to evaluate the impact of the malnutrition risk, determined by Seoul National University Hospital-nutrition screening index (SNUH-NSI), on operative morbidity after colorectal surgery for cancer.

Methods: This study enrolled 2,462 patients who had undergone colectomy for initially diagnosed colorectal cancer at Seoul National University Hospital from January 2011 to December 2014. We collected general patient information, SNUH-NSI and prognostic nutritional index (PNI) at administration and related parameters (serum albumin, cholesterol, total lymphocyte counts, hemoglobin and body mass index), operative method, hospital stay and operative morbidity.

Results: Patients' mean age was 62.12 years, and 423 patients (17.18%) were rated as severe malnutrition risk. Patients with high risk of malnutrition by SNUH-NSI or PNI, men, higher American Society of Anesthesiologists (ASA) class, palliative operation, and higher stage showed higher operative morbidity ($P < 0.05$). On multivariate analysis, significant independent risk factors for operative morbidity were severe malnutrition by SNUH-NSI (odds ratio [OR], 1.868; 95% confidence interval [CI], 1.429–2.442; $P < 0.001$) or PNI (OR, 1.596; 95% CI, 1.258–2.025; $P < 0.001$), men (OR, 1.483; 95% CI, 1.174–1.876; $P = 0.001$), or high ASA class (OR, 1.782; 95% CI, 1.136–2.795; $P = 0.012$).

Conclusion: Overall nutritional status, rather than single data, shows significant association with postoperative morbidity in patients who underwent colectomy. Especially severe malnutrition determined by SNUH-NSI, is an independent risk factor for perioperative morbidity. Nutritional support to severely malnourished patient by SNUH-NSI is expected to be effective in preventing complications after colectomy of colorectal carcinoma patients.

Keywords: Colorectal cancer, Colectomy, Malnutrition, Screening, Morbidity

INTRODUCTION

Colorectal cancer is the third most commonly occurring cancer in the world, and its incidence is gradually increasing [1]. Despite advances in treatment methods, the rates of recurrence and mortality from colorectal cancer remain high [2]. Surgery is an important

treatment method, but it may lead to surgical complications, which are associated with poor patient prognosis. The identification of factors predictive of complications can result in better patient prognosis.

Cancer patients are more likely to be malnourished than patients with other diseases [3], and association between preoperative nutrition and surgical outcome has been reported [4]. Malnutrition can delay treatment; increase infection, complication, and mortality rates; and prolong duration of hospital stay, leading to increased medical costs [5]. Since surgery may have major effects on treatment outcomes, surgical outcomes may be impaired by investigating nutritional and immune status.

The 2006 the European Society of Parenteral and Enteral Nutrition guidelines suggest that patients undergoing upper gastrointestinal surgery who are at risk of severe malnutrition require preop-

Received: Oct 1, 2017 Accepted: Dec 13, 2017

Correspondence to: Ji Won Park

Department of Surgery, Seoul National University Hospital and College of Medicine, 101 Daehak-ro, Jongno-gu, Seoul 03080, Korea

Tel: +82-2-2072-2325, Fax: +82-2-766-3975

E-mail: sowisdom@gmail.com

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erative nutritional support, even if surgery is delayed [6]. These guidelines, however, do not provide recommendations for colorectal cancer patients, and few studies have described the association between nutritional status and postoperative outcomes in patients with colorectal cancer.

Various preoperative nutrition screening tools have been developed [4,7-11]. The prognostic nutritional index (PNI) is commonly used, with many studies showing that the PNI is a significant in-

dicator of postoperative outcomes [4,7-11]. In addition, malnutrition risk, as determined by the Seoul National University Hospital-nutrition screening index (SNUH-NSI), was found to have a significant impact on postoperative complications in patients with gastric cancer [12].

The present study was designed to evaluate the risk of malnutrition at admission, as determined using nutrition screening tools, in patients undergoing colectomy for colorectal cancer, and to inves-

Table 1. Seoul National University Hospital-nutrition screening index (SNUH-NSI)

Variables	r1	r2	r3
Appetite	Normal/Good	-	Bad
Change of weight	No	-	Yes
Difficulty in digesting	No	Yes	-
Diet type	Normal regular diet	Soft blended diet	Fluid diet
Serum-albumin	≥ 3.3	≥ 2.8, < 3.3	< 2.8
Serum-cholesterol	≥ 130	< 130	-
Total lymphocyte count	≥ 1,500	≥ 800, < 1,500	< 800
Hemoglobin			
Male	≥ 13.0	< 13.0	-
Female	≥ 12.0	< 12.0	-
C-reactive protein	≤ 1	> 1	-
Body mass index (kg/m ²)	≥ 18, < 25	< 18 or ≥ 25	-
Age (yr)	≤ 75	> 75	-

High risk group, (more than 2 of r3) or (1 of r3+more than 2 of r2); Low risk group, the others.

r, risk factor.

Table 2. Definition of complications

Group	Classification	Definition
Wound complication	Wound infection	Re-suture (wound repair) or delay in discharge
Operation related complication	Intraabdominal fluid collection/abscess	Confirmed by CT, NPO or PCD required
	Intraabdominal bleeding	Transfusion or intervention (angiography, reoperation) required
	Intraluminal bleeding	Transfusion or intervention required
	Intestinal obstruction	Obstruction point (+), NPO or reoperation required, re-admission or ER visit (within 30 days)
	Ileus	Obstruction point (-), delay in discharge due to NPO
	Anastomosis stenosis	Confirmed by colonoscopy or colon study, intervention required
	Anastomosis leakage	Confirmed by fistulogram
	Pancreatitis	Confirmed by CT, delay in discharge due to NPO
	Enterocutaneous fistula	Confirmed by fistulogram
Systemic complication	Lymphatic leakage	Chylous drainage via Jackson-Pratt drainage, NPO or low fat diet required
	Stoma complication	Prolapse, necrosis, bleeding, retraction
	Pulmonary	Pleural effusion, pneumonia
	Renal/urinary	Urinary tract infection, acute renal failure
	Hepatic	Liver abscess, liver failure
	Cardiac	Myocardial infarction, heart infarction, arrhythmia
	Endocrine	Diabetes Insipidus, diabetic ketoacidosis, syndrome of inappropriate secretion of antidiuretic hormone
	Neurologic	Delirium, cognitive disorder, psychosis
	Thromboembolism	Deep vein thromboembolism, pulmonary thromboembolism

CT, computed tomography; NPO, nil per os (nothing by mouth); PCD, percutaneous drainage; ER, emergency room.

tigate the effects of preoperative malnutrition on the occurrence of postoperative complications.

METHODS

This retrospective study evaluated 3,746 patients who were admitted to Seoul National University Hospital (SNUH) for primary colorectal cancer and who underwent colectomy from January

2011 to December 2014. Patients with a history of other cancers, recurrent colorectal cancer, or hereditary colorectal cancer; and patients who underwent combined resection of other organs or had insufficient data for analysis were excluded from this study. The study cohort consisted of 2,462 patients, with patient data retrospectively collected from electronic medical records. The study protocol was approved by the Institutional Review Board of SNUH (IRB no. H-1712-043-905).

Table 3. General characteristics of the subjects

Variable	Total (n = 2,462)	SNUH-NSI		P-value
		High risk group (n = 423)	Low risk group (n = 2,039)	
Age (yr)	62.12 ± 11.25	64.22 ± 12.12	61.84 ± 11.01	< 0.001
< 60	996 (40.45)	145 (34.28)	851 (41.74)	0.004
≥ 60	1,466 (59.55)	278 (65.72)	1,188 (58.26)	
Sex				0.851
Male	1,500 (60.93)	256 (60.52)	1,244 (61.01)	
Female	962 (39.07)	167 (39.48)	795 (38.99)	
ASA classification				< 0.001
1	938 (38.10)	129 (30.50)	809 (39.68)	
2	1,420 (57.68)	255 (60.28)	1,165 (57.14)	
3	103 (4.18)	38 (8.98)	65 (3.19)	
4	1 (0.04)	1 (0.24)	0 (0.0)	
Body mass index (kg/m ²)	23.38 ± 3.36	22.39 ± 3.66	23.58 ± 3.216	< 0.001
< 18.5	145 (5.89)	59 (13.95)	86 (4.22)	
≥ 18.5, < 23	1,030 (41.84)	202 (47.75)	828 (40.61)	
≥ 23, < 25	580 (23.56)	71 (16.78)	509 (24.96)	
≥ 25	707 (28.72)	91 (21.51)	616 (30.21)	
Smoking				0.727
No	1,946 (79.04)	337 (79.67)	1,609 (78.91)	
Yes	516 (20.96)	86 (20.33)	430 (21.09)	
Alcohol intake				0.040
No	1,707 (69.33)	311 (73.52)	1,396 (68.46)	
Yes	755 (30.67)	112 (26.48)	643 (31.54)	
Stage				< 0.001
0-1	512 (20.80)	45 (10.64)	467 (22.90)	
2	703 (28.55)	124 (29.31)	579 (28.40)	
3	868 (35.26)	132 (31.21)	736 (36.10)	
4	379 (15.39)	122 (28.84)	257 (12.60)	
Curative/Palliative surgery				< 0.001
Curative	2,251 (91.47)	328 (77.73)	1,923 (94.31)	
Palliative	210 (8.53)	94 (22.27)	116 (5.69)	
Surgical approach				< 0.001
Open	1,743 (70.80)	337 (79.67)	1,406 (68.96)	
Laparoscopic	719 (29.20)	86 (20.33)	633 (31.04)	
Tumor location				< 0.001
Colon	799 (32.45)	173 (40.90)	626 (30.70)	
Rectosigmoid	1,658 (67.34)	247 (58.39)	1,411 (69.20)	
Both	5 (0.2)	3 (0.6)	2 (0.1)	
Hospital stay (day)	7.94 ± 5.07	9.85 ± 6.99	7.55 ± 4.47	< 0.001

Values are presented as mean ± standard deviation or number (%).

SNUH-NSI, Seoul National University Hospital-nutrition screening index; ASA, American Society of Anesthesiologists.

Nutrition screening tools

The risk of malnutrition in patients was assessed within 24 hours of admission using the SNUH-NSI. The SNUH-NSI was determined from parameters such as age, body mass index (BMI), changes in weight, appetite, digestive disorders, and meal pattern at admission. Other factors included in the SNUH-NSI were serum albumin, total cholesterol level, and C-reactive protein (CRP) concentrations; total lymphocyte count; and hemoglobin level measured within 2 weeks before admission. Based on these parameters, the risk of malnutrition was classified as r1, r2, and r3 [13-16], with the patients classified into a high-risk group and a low-risk group for malnutrition (Table 1).

Nutrition status was also classified using the PNI, a widely used nutrition screening tool. The PNI was calculated using the formula: albumin concentration (g/dL) $\times$ 10 + total lymphocyte count $\times$ 0.005 (/mm³).

Patient data

Baseline demographic and clinical information collected from patients' electronic medical records included age, sex, American Society of Anesthesiologists (ASA) classification, smoking status, history of alcohol intake, clinical stage, radical or palliative surgery, operative methods, tumor location, presence or absence of postoperative complications, and nutritional risk group. The postoperative complications were classified as shown in Table 2.

Statistical analysis

General characteristics and anthropometric factors were expressed as mean $\pm$ standard deviation, and its number and percentage was counted. Continuous variables were compared using t-tests and analysis of variance test, and categorical variables were compared using chi-square tests. Multivariate logistic regression analysis was performed to analyze factors independently predictive of the risk of complications. Statistical significance was defined as a P-value < 0.05 . All statistical analyses were performed using SPSS ver. 22.0 K for Windows (IBM Corp., Somers, NY, USA).

RESULTS

General characteristics of the subjects

The demographic and clinical characteristics of the 2,462 patients in the study population are shown in Table 3. Preoperative nutritional screening showed that 423 patients (17.18%) were in the high-risk group for malnutrition and 2,039 (82.82%) were in the low-risk group for malnutrition according to SNUH-NSI scores. The mean age of all patients was 62.12 ± 11.25 years, and was significantly higher in the group at high than at low risk for malnutrition (64.22 ± 12.12 vs. 61.84 ± 11.01 years, $P < 0.001$). The mean postoperative length of stay was 7.94 ± 5.07 days and was significantly longer in the group at high than at low risk for malnutrition (9.85 ± 6.99 vs. 7.55 ± 4.47 days, $P < 0.001$). The mean BMI was 23.38 ± 3.36 kg/m², with 145 (5.89%) patients having a BMI < 18.5 .

Table 4. Incidence of postoperative morbidity ($P < 0.001$)

Complication	High risk group (n = 423)	Low risk group (n = 2,039)	Total (n = 2,462)
Wound infection	14 (3.3)	32 (1.6)	46 (1.9)
Intraabdominal fluid collection/abscess	4 (0.9)	8 (0.4)	12 (0.5)
Intraabdominal bleeding	1 (0.2)	0	1 (<0.1)
Intestinal obstruction	0	0	0
Ileus	7 (1.7)	36 (1.8)	43 (1.7)
Stenosis	9 (2.1)	24 (1.2)	33 (1.3)
Anastomotic leakage	0	3 (0.1)	3 (0.1)
Enterocutaneous fistula	0	2 (0.1)	2 (0.1)
Lymphatic leakage	3 (0.7)	15 (0.7)	18 (0.7)
Stoma	0	2 (0.1)	2 (0.1)
Pancreatitis	0	0	1 (0.03)
Pulmonary	9 (2.1)	16 (0.8)	25 (1.0)
Renal/Urinary	2 (0.5)	18 (0.9)	20 (0.8)
Cardiac	1 (0.2)	3 (0.1)	4 (0.2)
Hepatic dysfunction	0	0	0
Neurologic	1 (0.2)	3 (0.1)	4 (0.2)
Thromboembolism	0	1 (<0.1)	1 (<0.1)
Mutiple	57 (13.5)	121 (5.9)	178 (7.2)
Total	108 (25.5)	283 (13.9)	391 (15.9)

kg/m² and 707 (28.72%) having a BMI $\geq$ 25 kg/m².

Of the 2,462 patients in the study cohort, 1,247 (50.65%) had stages 3 and 4 colorectal cancer, 1,658 (67.34%) had cancers in the rectum and sigmoid colon and 1,743 (70.80%) underwent open surgery. The risk of malnutrition did not differ according to sex or smoking status, but differed significantly according to age, ASA class, BMI, drinking status, clinical stage, radical resection, operative method, and tumor location ($P < 0.05$ each).

Postoperative complications

Of the 2,462 patients, 391 (15.9%) experienced postoperative com-

plications. As a single complication, wound infection was the most frequent complication, which occurred in 46 subjects (1.9%). Other single postoperative complications included intestinal obstruction in 43 patients (1.7%), colonic stricture in 33 (1.3%), pulmonary complications in 25 (1.0%), and renal and urologic complications in 20 (0.8%) (Table 4). The incidence of complications was significantly higher in the group at high than at low risk for malnutrition (25.5% vs. 13.9%, $P < 0.001$).

The relationship between the incidence of complications and risk of malnutrition differed, however, when the complications were classified as wound-related, operation-related, and systemic complications (Table 2). The incidence of wound-related complications was significantly higher in the group at high than at low risk for malnutrition (3.3% vs. 1.6%, $P = 0.016$). However, the rates of operation-related complications (5.2% vs. 4.4%, $P = 0.480$) and systemic complications (3.3% vs. 2.0% $P = 0.100$) did not differ significantly in the groups at high risk than at low risk of malnutrition.

Factors affecting the occurrence of complications

Univariate analysis showed that factors associated with a higher incidence of overall postoperative complications included a higher risk of malnutrition ($P < 0.001$), male sex ($P = 0.001$), a higher ASA score ($P < 0.001$), palliative surgery ($P = 0.004$), and higher clinical stage ($P = 0.004$) (Table 5). History of smoking, history of alcohol intake, operative method, and tumor location of tumors did not affect the incidence of overall complications. Multivariate analysis showed that a high risk for malnutrition according to both the SNUH-NSI score (odds ratio [OR], 1.868; 95% confidence interval [CI], 1.429–2.442; $P < 0.001$) and PNI score (OR, 1.596; 95% CI, 1.258–2.025; $P < 0.001$), male sex (OR, 1.483; 95% CI, 1.174–1.876; $P = 0.001$), and a high ASA class (OR, 1.782; 95% CI, 1.136–2.795; $P = 0.012$) were independent risk factors for the occurrence of complications (Table 6).

DISCUSSION

Surgery or trauma may increase catabolism and result in hypermetabolism, increasing protein and energy requirements [17]. This may lead to postoperative complications. Many factors have been associated with the occurrence of complications, including nutritional status [4,18,19]. Indeed, malnutrition has been reported in 30%–50% of patients who undergo gastrointestinal surgery [20]. Complications associated with nutritional status may prolong length of hospital stay and increase medical costs [21].

The present study provides additional evidence that nutritional status may affect surgical outcomes. This study found that the risk of malnutrition, in addition to low ASA class and sex, were factors

Table 5. Univariate analysis of risk factors for postoperative morbidity

Variable	No. of patients	No. with complications (%)	P-value
Sex			0.001
Male	1,500	269 (17.9)	
Female	962	122 (12.7)	
ASA class			< 0.001
1, 2	2,358	360 (15.3)	
3, 4	104	31 (29.8)	
Smoking			0.275
No	1,946	301 (15.5)	
Yes	516	90 (17.4)	
Alcohol			0.710
No	1,707	256 (15.0)	
Yes	755	135 (17.9)	
Curative/Palliative surgery			0.004
Curative	2,251	343 (15.2)	
Palliative	210	48 (22.9)	
SNUH-NSI			< 0.001
Low risk group	2,039	279 (13.7)	
High risk group	423	112 (26.5)	
PNI			< 0.001
Low risk group (> 45.5)	1,732	226 (13.0)	
High risk group ($\leq$ 45.5)	730	165 (22.6)	
Surgery approach			0.175
Open	1,743	288 (16.5)	
Laparoscopic	719	103 (14.3)	
Tumor location			0.125
Colon	799	144 (18.0)	
Rectosigmoid	1,658	246 (14.8)	
Both	5	1 (20.0)	
Stage			0.005
0–1	512	66 (12.9)	
2	703	116 (16.5)	
3	868	128 (14.7)	
4	379	81 (21.4)	

ASA, American Society of Anesthesiologists; SNUH-NSI, Seoul National University Hospital-nutrition screening index; PNI, prognostic nutritional index.

Table 6. Multivariate analysis of risk factors for postoperative morbidity

Variables	No.	P-value	Odds ratio	95% Confidence interval
SNUH-NSI				
Low risk group	2,039	Reference		
High risk group	423	< 0.001	1.868	1.429–2.442
PNI				
Low risk group (> 45.5)	1,732	Reference	1.596	1.258–2.025
High risk group ($\leq$ 45.5)	730	< 0.001		
Sex				
Female	962	Reference	1.483	1.174–1.876
Male	1,500	0.001		
ASA class				
1, 2	2,358	Reference	1.782	1.136–2.795
3, 4	104	0.012		

SNUH-NSI, Seoul National University Hospital-nutrition screening index; PNI, prognostic nutritional index; ASA, American Society of Anesthesiologists.

affecting complications and contributed significantly to surgical outcomes.

Many attempts have been made to develop nutritional screening indices to assess patients' nutritional status. Serum albumin concentration has been the most commonly used single factor, with many studies suggesting that serum albumin level < 3.5 g/dL is an independent risk factor for postoperative complications [22–24]. Because serum albumin has a relatively long half-life, and its concentration is highly affected by changes in non-nutritional factors, such as volume status or disease status, it may not accurately reflect recent nutritional status [22]. Other factors, such as serum total cholesterol concentration and total lymphocyte count, have been used to assess nutritional status in many clinical settings. However, these biochemical markers are also likely affected by factors other than nutritional status, limiting their individual value [22,25,26].

To overcome the limitations of these single factors, various nutrition screening tools have been developed to assess patients' overall nutritional status [7]. These include the PNI, the Nutrition Risk Screening-2002 (NRS-2002), the Malnutrition Universal screening tool, the Mini Nutritional Assessment, the Short Nutritional Assessment Questionnaire, and the malnutrition screening tool (MST). The PNI was found to be a significant factor affecting postoperative outcomes in patients with colorectal cancer [11]. The NRS-2002 classifies nutritional status based on three factors, nutritional status based on BMI, weight loss and changes in intake; severity of disease by diagnosis; and age, with nutritional risk being a significant predictor of postoperative complications [4,9].

Although use of these screening tools may enable effective nutritional assessment, differences in the characteristics of patients between hospitals may result in differences in screening criteria that can sensitively reflect the risk of malnutrition. Some medical institutions have therefore developed their own nutritional screening

tools and are making efforts to verify their validity. The SNUH has developed its own screening tool, the SNUH-NSI, to assess the nutritional status of patients [27]. The SNUH-NSI includes several parameters, including age; BMI; changes in body weight; appetite; digestive disorders and meal patterns at admission; serum concentrations of albumin, total cholesterol, and CRP; total lymphocyte counts, and hemoglobin level measured within 2 weeks before admission. In addition to measures of current weight, such as BMI, weight changes over time are recognized as important indices reflecting malnutrition [13,14,22]. Other factors included in the SNUH-NSI, such as appetite status, meal pattern and digestive symptoms, are also included in other nutritional assessment and screening tools, such as the Subjective Global Assessment (SGA), the Patient Generated-SGA (PG-SGA) and the NRS-2002. CRP is not a direct indicator of malnutrition, but is associated with inflammation and infection, which increase nutritional requirements. Elevated CRP is negatively associated with nutrition-related markers, such as prealbumin concentration, and has been reported to be an index associated with mortality of hospitalized patients [28]. The SNUH-NSI is a practical index for use in clinical settings with limited manpower and resources, because information on each parameter can be collected using an automatic screening system in the hospital. This tool can provide more specific information than a single parameter such as albumin concentration, and is relatively convenient to use compared with other nutritional assessment tools.

Other nutrition screening tools developed by individual medical institutions include the Gangnam Severance Hospital Nutritional Risk Screening Tool, the National Cancer Center Malnutrition Screening Tool for Cancer patients, and the Seoul National University Bundang Hospital nutrition screening index [7]. Both the SNUH-NSI and the NRS showed moderate agreement with the

results of in-depth nutritional assessment using the PG-SGA, confirming that the SNUH-NSI and the NRS are suitable for use as nutrition screening tools [7].

Although many studies have assessed preoperative nutritional status in patients with cancers of the upper gastrointestinal tract and other organs, relatively few studies have analyzed preoperative nutritional status in patients with colorectal cancer. The present study used both the PNI and the SNUH-NSI to assess nutritional status, finding that these preoperative screening tools differed significantly in predicting complications, with the SNUH-NSI (OR, 1.868) being a stronger predictor of complications after colorectal cancer surgery than the PNI (OR, 1.596), indicating that the SNUH-NSI can be of value as a nutritional screening tool.

This study had several limitations, including its retrospective design and its inclusion of patients at a single institution. However, the number of patients was significantly larger compared with those of previous studies. In addition, it was difficult to determine the details of each operation that could affect postoperative complications. However, because they were elective surgeries, performed by experienced surgeons using standardized surgical procedures, these effects were regarded as not significant.

Despite these limitations, the use of nutritional screening tools to identify patients at risk of malnutrition may be clinically useful in predicting postoperative complications in patients with colorectal cancer. Nutritional screening tools such as the SNUH-NSI can be used to more easily predict complications in patients undergoing colorectal cancer surgery. As individualized and personalized health care is becoming more important these days, nutritional assessment of an individual by optimized tool will be useful.

The SNUH-NSI, a nutritional screening tool, based on blood test results, such as serum albumin and total cholesterol and hemoglobin concentrations, appetite, weight changes, dyspepsia, meal pattern, age and BMI at admission is an independent risk factor for complications in patients undergoing surgery for colorectal cancer. Preoperative nutritional screening may help predict postoperative complications and improve clinical prognosis. Further studies on more specific clinical effects are needed.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

This research was partly supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. NRF2017R1D1A1B

03036191) and partly supported by supported by grant no. 042 0170600 (2017-1249) from the SNUH Research Fund.

REFERENCES

1. Brenner H, Kloor M, Pox CP. Colorectal cancer. *Lancet* 2014; 383:1490-502.
2. Winawer S, Fletcher R, Rex D, Bond J, Burt R, Ferrucci J, et al. Colorectal cancer screening and surveillance: clinical guidelines and rationale-Update based on new evidence. *Gastroenterology* 2003; 124:544-60.
3. Ryan AM, Power DG, Daly L, Cushen SJ, Ni Bhuachalla E, Prado CM. Cancer-associated malnutrition, cachexia and sarcopenia: the skeleton in the hospital closet 40 years later. *Proc Nutr Soc* 2016; 75:199-211.
4. Schwegler I, von Holzen A, Gutzwiller JP, Schlumpf R, Muhlebach S, Stanga Z. Nutritional risk is a clinical predictor of postoperative mortality and morbidity in surgery for colorectal cancer. *Br J Surg* 2010;97:92-7.
5. Cooper C, Brierley ER, Burden ST. Improving adherence to a care plan generated from the Malnutrition Universal Screening Tool. *Eur J Clin Nutr* 2013;67:174-9.
6. Weimann A, Braga M, Harsanyi L, Laviano A, Ljungqvist O, Soeters P, et al. ESPEN Guidelines on Enteral Nutrition: surgery including organ transplantation. *Clin Nutr* 2006;25:224-44.
7. Seol E, Ju DL, Lee HJ. Nutritional screening tool for in-hospital patients. *J Clin Nutr* 2016;8:2-10.
8. Hirashima K, Watanabe M, Shigaki H, Imamura Y, Ida S, Iwatsuki M, et al. Prognostic significance of the modified Glasgow prognostic score in elderly patients with gastric cancer. *J Gastroenterol* 2014;49:1040-6.
9. Kwag SJ, Kim JG, Kang WK, Lee JK, Oh ST. The nutritional risk is a independent factor for postoperative morbidity in surgery for colorectal cancer. *Ann Surg Treat Res* 2014;86:206-11.
10. Watanabe M, Iwatsuki M, Iwagami S, Ishimoto T, Baba Y, Baba H. Prognostic nutritional index predicts outcomes of gastrectomy in the elderly. *World J Surg* 2012;36:1632-9.
11. Noh GT, Han J, Cho MS, Hur H, Min BS, Lee KY, et al. Impact of the prognostic nutritional index on the recovery and long-term oncologic outcome of patients with colorectal cancer. *J Cancer Res Clin Oncol* 2017;143:1235-42.
12. Kim Y, Kim WG, Lee HJ, Park MS, Lee YH, Cho JJ, et al. Impact of malnutrition risk determined by nutrition screening index on operative morbidity after gastric cancer surgery. *J Korean Surg Soc* 2011;80:1-9.
13. Lee RD, Nieman DC. Nutritional assessment. Maidenhead: McGraw-Hill Education; 2005.

14. Charney P, Malone A, American Dietetic A. ADA pocket guide to nutrition assessment. Chicago: American Dietetic Association; 2009.
15. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. *Clin Nutr* 2003;22:415-21.
16. Kondrup J, Rasmussen HH, Hamberg O, Stanga Z. Nutritional risk screening (NRS 2002): a new method based on an analysis of controlled clinical trials. *Clin Nutr* 2003;22:321-36.
17. Hill AG, Hill GL. Metabolic response to severe injury. *Br J Surg* 1998;85:884-90.
18. Sungurtekin H, Sungurtekin U, Balci C, Zencir M, Erdem E. The influence of nutritional status on complications after major intraabdominal surgery. *J Am Coll Nutr* 2004;23:227-32.
19. Sorensen J, Kondrup J, Prokopowicz J, Schiesser M, Krahenbuhl L, Meier R, et al. EuroOOPS: an international, multicentre study to implement nutritional risk screening and evaluate clinical outcome. *Clin Nutr* 2008;27:340-9.
20. Schiesser M, Kirchhoff P, Muller MK, Schafer M, Clavien PA. The correlation of nutrition risk index, nutrition risk score, and bioimpedance analysis with postoperative complications in patients undergoing gastrointestinal surgery. *Surgery* 2009;145:519-26.
21. Shulkin DJ, Kinosian B, Glick H, Glen-Puschett C, Daly J, Eisenberg JM. The economic impact of infections: an analysis of hospital costs and charges in surgical patients with cancer. *Arch Surg* 1993;128:449-52.
22. Elliott L, Molseed LL, McCallum PD, American Dietetic A, Oncology Nutrition Dietetic Practice G. The clinical guide to oncology nutrition. Chicago, IL: American Dietetic Association; 2006.
23. Gibbs J, Cull W, Henderson W, Daley J, Hur K, Khuri SF. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the National VA Surgical Risk Study. *Arch Surg* 1999;134:36-42.
24. Putwatana P, Reodecha P, Sirapo-ngam Y, Lertsithichai P, Sumboonnanonda K. Nutrition screening tools and the prediction of postoperative infectious and wound complications: comparison of methods in presence of risk adjustment. *Nutrition* 2005;21:691-7.
25. Oh CA, Kim DH, Oh SJ, Choi MG, Noh JH, Sohn TS, et al. Changes of the preoperative and postoperative nutritional statuses in patients with gastric cancer and assessment of the nutritional factors that are correlated with short-term postoperative complications. *J Korean Gastric Cancer Assoc* 2010;10:5-12.
26. Lee MS. Nutritional management in gastric cancer patients. *J Korean Gastric Cancer Assoc* 2003;3:172-7.
27. Kim Y, Kim WG, Lee HJ, Park MS, Lee YH, Kong SH, et al. Comparison of the impact of malnutrition by nutritional assessment and screening tools on operative morbidity after gastric cancer surgery. *J Korean Soc Parenter Enter Nutr* 2011;4:7-15.
28. Fein PA, Mittman N, Gadh R, Chattopadhyay J, Blaustein D, Mushnick R, et al. Malnutrition and inflammation in peritoneal dialysis patients. *Kidney Int Suppl* 2003;(87):S87-91.