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Applicability of five nutritional screening tools in Chinese patients undergoing colorectal cancer surgery: a cross-sectional study

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ABSTRACT

Objectives To identify the most appropriate nutritional risk screening tool for patients undergoing colorectal cancer surgery, five nutritional screening tools, including the Nutritional Risk Screening 2002 (NRS 2002), Short Form of Mini Nutritional Assessment (MNA-SF), Malnutrition Universal Screening Tool (MUST), Malnutrition Screening Tool (MST) and Nutritional Risk Index (NRI), were employed to evaluate the nutritional risk at admission and short-term clinical outcome prediction.

Design A cross-sectional study.

Setting A comprehensive affiliated hospital of a university in Shenyang, Liaoning Province, China.

Participants 301 patients diagnosed with colorectal cancer were continuously recruited to complete the study from October 2020 to May 2021.

Primary and secondary outcome measures Within 48 hours of hospital admission, five nutritional screening tools were used to measure the nutritional risk and to determine their relationship with postoperative short-term clinical outcomes.

Results The nutritional risk assesed by the five tools ranged from 25.2% to 46.2%. Taking the Subject Global Assessment as the diagnostic standard, MNA-SF had the best consistency (κ=0.570, p<0.001) and MST had the highest sensitivity (82.61%). Multivariate Logistic regression analysis after adjusting confounding factors showed that the NRS 2002 score ≥3 (OR 2.400, 95% CI 1.043 to 5.522) was an independent risk factor for postoperative complications and was the strongest predictor of postoperative complications (area under the curve 0.621, 95% CI 0.549 to 0.692). The scores of NRS 2002 (r=0.131, p<0.001), MNA-SF (r=0.115, p<0.05) and NRI (r=0.187, p<0.05) were poorly correlated with the length of stay. There was no correlation between the five nutritional screening tools and hospitalisation costs (p>0.05).

Conclusions Compared with the other four nutritional screening tools, we found that NRS 2002 is the most appropriate nutritional screening tool for Chinese patients with colorectal cancer.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ As far as we know, it was the first time that five nutrition screening tools have been used simultaneously to evaluate the nutritional risk at admission in patients with colorectal cancer in China.
- ⇒ For the first time, we compared the diagnostic value of five nutritional screening tools simultaneously based on the occurrence of short-term postoperative complications of grade II or above.
- ⇒ Patient selection bias may be present since patients with operable colorectal cancer who decided not to have surgery and patients receiving cancer treatment prior to admission were excluded.
- ⇒ Given that the data originate from a single research centre, the universality of the results is limited.

INTRODUCTION

Colorectal cancer (CRC) is the third most common cancer and the fourth-leading cause of cancer-related deaths worldwide, and its burden is expected to increase by 60% to >2.2 million new cases and >1.1 million cancer deaths by 2030.[1] Patients with CRC often suffer from intestinal dysfunction due to chronic blood loss, cancer ulceration, surgery and chemoradiotherapy, resulting in decreased digestive and absorption functions, abnormal nutrition metabolism or intestinal obstruction. Related studies revealed that approximately 40%–65% of patients with CRC were diagnosed with malnutrition at various stages of the disease.[2 3] Unfortunately, one study[4] reported that 50% of patients with CRC suffer from weight loss and 20% of patients with CRC are diagnosed with malnutrition on admission to a hospital, which suggested that preoperative malnutrition is common in patients with CRC. Malnutrition can have a negative impact on the prognosis of patients with CRC by reducing the response and tolerance to cancer treatment and increasing the risk of postoperative complications.[5 6] Another study demonstrated that nutritional risk screening may be able to predict mortality and morbidity following CRC surgery.[7] Moreover, malnutrition also increases the length of hospital stay, disease burden and impacts

the quality of life.[8 9] Even some studies[10 11] revealed that the lack of adequate nutritional screening tools was even considered as one of the reasons for not starting nutritional support. Therefore, identifying patients with malnutrition or nutritional risk, and those who would benefit from specific nutritional support, are critical in reducing the risk of surgical complications, improving clinical outcomes and reducing medical expenses.

There are a variety of nutritional screening tools, such as Nutritional Risk Screening 2002 (NRS 2002), Short Form of Mini Nutritional Assessment (MNA-SF), Malnutrition Universal Screening Tool (MUST), Malnutrition Screening Tool (MST), Nutritional Risk Index (NRI) and so on. Most of these nutrition screening tools belong to universal screening tools, and it has not been determined which is the best for patients with CRC. Subjective Global Assessment (SGA) has been tested and validated in different clinical environments, and it is usually used as a criterion for comparing different nutrition screening tools and verifying new assessment tools.[12 13] However, because SGA is a subjective tool, its application requires trained professionals, and the investigation time of using SGA is 2–3 times longer than that of other tools, which hinders its use in clinical practice.[14 15] Therefore, in this study, we investigated the prevalence of nutritional risk in patients undergoing CRC surgery by using five nutritional screening tools, to compare whether they are sufficient to evaluate the nutritional risk and predict clinical outcomes of patients undergoing CRC surgery.

METHODS

Study design

This cross-sectional study was conducted at the First Hospital of China Medical University. Patients were initially diagnosed with CRC and underwent surgery between October 2020 and May 2021. Other inclusion criteria were age ≥18 years old, no tumour intervention such as surgery, chemoradiotherapy and biological immunotherapy before admission, no serious dysfunction of important organs such as heart, liver, lung and kidney, clear consciousness, and complete case data. The exclusion criteria were patients with systemic oedema, ascites, severe diarrhoea or dehydration, patients with other consumptive diseases (such as severe liver and kidney disease, hyperthyroidism, pulmonary tuberculosis, severe digestive system diseases, etc), patients receiving enteral or parenteral nutrition support, and patients requiring a stay in bed strictly during hospitalisation. The study is in line with the principles of the Declaration of Helsinki. The survey was conducted within the first 48 hours after admission.

Patients and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination of this study.

Data collection

On admission, demographic data (such as age, sex, payment methods, smoking history, alcohol consumption history, etc) and disease-related data (such as medical diagnosis, pathological stages, surgical methods, comorbidities, etc) were collected by trained investigators. Five nutritional screening tools were used to evaluate the nutritional risk of the patients within 48 hours after admission. Clinical outcomes (including complications, length of hospital stay and hospitalisation costs) were observed and recorded within 1 month after surgery. The severity of postoperative complications was classified according to Clavien-Dindo[16] and the postoperative complications recorded in this study were grade II or above. To ensure standardisation of the screening, all researchers participated in a training session before the study began.

Nutrition risk screening tools

The NRS 2002[17] was proposed by the European Society for Parenteral and Enteral Nutrition in 2002 based on 128 clinical randomised trials and recommended as one of the primary screening tools for nutritional risk. This tool contains a disease severity score, a nutritional impairment score and an age score. The total score ranges from 0 to 7. A total score ≥3 indicates nutritional risk, while a score <3 indicates well-nourished, and the nutritional assessment is repeated weekly. Finally, the NRS 2002 score ≥3 was defined as a nutritional risk in this study.

The MNA-SF[18] is the short form of MNA, and it is designed especially for the elderly. It contains six questions selected from MNA. These questions are about recent weight loss, changes in appetite, mobility, psychological stress, neuropsychological problems and body mass index (BMI). The scores of each question ranged from 0 to 3, and the total score is 14. According to the score, the patients are divided into three groups: good nutrition group (12–14 points), malnutrition risk group (8–11 points) and malnutrition group (≤7 points). In this study, MNA-SF ≤11 was defined as nutritional risk.

MUST[19] score is calculated by patient's BMI, unplanned weight loss during the previous 3–6 months, and any acute disease which the patient found it almost impossible to eat for more than 5 days. The summed scores were divided into 3 degrees: 0 is at low risk of malnutrition, score 1 is at moderate risk of malnutrition, and score 2 is at high risk of malnutrition. In our study, patients with a score of ≥1 were classified as nutritional risk.

MST[20] is a simple, valid and reliable nutritional screening tool designed by Ferguson *et al*[20] to identify patients at nutrition risk. The MST involves two questions: recent unconscious weight loss and reduced oral intake (secondary to poor appetite). According to the total score, the patients are divided into two groups: malnutrition risk (MST score ≥2) and no malnutrition risk (MST score <2). MST proved to have good sensitivity and specificity in adult inpatients,[21 22] but relatively few studies have been conducted in cancer patients.[23–25] In this study, MST ≥2 was defined as nutritional risk.

NRI[26] is a nutritional risk index based on serum albumin concentration and weight loss rate. Its formula is: NRI=1.519 × [serum albumin(gm/dL)]+0.417× (current

weight/usual weight). According to the NRI score, a score ≥100 is well nourished, 97.5–100 is mild malnourished, 83.5–97.5 is moderately malnourished, and <83.5 is severely malnourished. In this study, the value of NRI<100 was defined as a nutritional risk, and the value of NRI ≥100 was defined as good nutrition.

Reference standard: SGA

Nutritional risk of the participants was measured using the assessment tool SGA[13 27] including weight, diet, activity, gastrointestinal symptoms, stress response, muscle consumption, subcutaneous fat changes and other eight items. The assessment results for each item are divided into three grades A, B and C. When five or more items are screened as grade A, it means well-nourished, and when more than five items are screened as grade B or C, it is suggested that it is moderate (or suspected) or severe malnutrition. In this study, we classified the evaluation results (B/C) of SGA as nutritional risk and used it as the gold standard of nutritional screening for comparative analysis with the other five nutritional screening tools.

The introduction of the nutritional screening tools used in this study is summarised in online supplemental table 1.

Sample size and statistical analysis

The minimum sample size was 89 patients with 36.2%[28] postoperative complications in patients with CRC (p=0.362, α=0.05 and d=0.1). The definitive sample size for this study was 301 cases. Statistical analysis was conducted using SPSS V.26.0 software for Windows. The counting data were described by frequency and percentage. Independent t-test and Pearson's χ2 test (or Fisher's exact test) were applied to the appropriate comparison of variables. For continuous variables, we used the Kolmogorov-Smirnov test to verify the normality of the data distribution. For normally distributed variables, mean and SD is reported, non-normal distributions are described by median and IQR. Mann-Whitney U test was performed for continuous variables and ordered categorical variables that do not follow the normal distribution. The Cohen's kappa coefficient was calculated to determine diagnostic concordance between the five nutritional screening tools and the diagnostic criteria for the malnutrition of SGA. The sensitivity, specificity, positive predictive value and negative predictive value of each nutritional screening tool were calculated by standard formula, respectively. Univariate analysis and multivariate logistic regression analyses were performed to identify the risk factors associated with postoperative complications in patients with CRC. Receiver operating characteristic (ROC) curves of the five screening tools were also used to evaluate the ability to accurately predict the postoperative complications of grade II or above. The correlations between five nutritional screening tools and length of stay (LOS) and cost of hospitalisation were evaluated by the Pearson test. A p<0.05 was deemed statistically significant.

RESULTS

Characteristics of the study population

In this study, the nutritional risk of 301 patients with CRC was examined within 48 hours of being admitted. The average age (mean±SD) was 62.78±10.56 years (range from 24 to 87). A total of 123 cases (40.9%) were women, and 178 cases (59.1%) were men. Patients with a monthly income of between 1000 and 3000 Ren Min Bi accounted for the largest proportion of 60.5%. Married patients had the highest proportion, up to 86.1%. 136 patients (45.2%) were diagnosed with CRC and 165 (54.8%) were diagnosed with rectal cancer. Patients who had comorbidities accounted for 38.2%. The mean BMI was 23.70±3.11 kg/m^2 (range from 16.98 to 37.11). 27.6% of the patients had grade II or above complications within 1 month after the operation. The mean length of hospitalisation was 19.20±6.69 days (range from 9 to 53). The mean hospitalisation cost was 75472.81±22 048.11 Ren Min Bi (range from 16 985.00 to 262111.00). The specific data of the patients are shown in table 1.

Evaluation results of five nutritional screening tools

Table 2 lists the evaluation results and comparative analysis of five nutritional screening tools. The incidence of nutritional risk classified by the NRS 2002, MNA-SF, MUST, MST, NRI and SGA was 41.5%, 46.2%, 39.5%, 30.6%, 25.2% and 43.5%, respectively. The tool with the highest level of consistency with the results of SGA was MNA-SF (κ=0.570, p<0.001), and the tool with the lowest level of consistency were NRI (κ=0.250, p<0.001). Taking the SGA as the benchmark, MST has the highest sensitivity of 82.61%, with a specificity of 73.68%, a positive predictive value of 58.02% and a negative predictive value of 90.59%. The NRI showed the lowest sensitivity, 60.00%, with a specificity of 73.68%, a positive predictive value of 58.02% and a negative predictive value of 74.12%.

Logistic regression analysis of postoperative complications

The univariate analysis was performed on the characteristics of patients and five nutritional screening tools, with statistically significant variables (p<0.05) as independent variables, and with the occurrence of postoperative complications of grade II and above as dependent variables, and the multivariate logistic regression model was used for further analysis. The results showed that only NRS 2002 (≥3 points) (OR 2.400, 95% CI 1.043 to 5.522) was independently associated with the postoperative complications of grade II or above (table 3).

Predictive value of five nutritional screening tools for complications

The ROC curve showed that the area under the curve (AUC) of the NRS 2002 and SGA were significantly larger than those of other tools, which suggested that NRS 2002 and SGA were similar in detecting postoperative complications and were the strongest predictors of postoperative complications in patients with CRC (AUC, 0.892 and AUC, 0.885, respectively). The MST did not have a

Table 1 Characteristics of the study population

Variable	N=301
Age (years)	62.78±10.56(24–87)
<60	100 (33.2)
≥60	201 (66.8)
Gender	
Male	178 (59.1)
Female	123 (40.9)
Monthly income (RMB)	
<1000	53 (17.6)
1000–3000	129 (42.9)
3001–5000	85 (28.2)
5001–10000	29 (9.6)
>10 000	5 (1.7)
Marital status	
Spinsterhood	1 (0.3)
Married	259 (86.1)
Divorced	12 (4.0)
Widowed	29 (9.6)
Diagnosis	
Colon cancer	136 (45.2)
Rectal cancer	165 (54.8)
Operation	
Laparoscopy	235 (78.1)
Open	66 (21.9)
Comorbidity	
Yes	115 (38.2)
No	186 (61.8)
BMI (mean±SD) (range)	23.70±3.11(16.98–37.11)
Complication (≥II)	
Yes	83 (27.6)
No	218 (72.4)
LOS (days±SD) (range)	19.20±6.69(9-53)
Hospitalisation cost	75472.81±22 048.11(16 985.00–262111.00)

Values are mean±SD (with ranges in brackets) or n (%), respectively.
BMI, body mass index; LOS, length of stay; RMB, Ren Min Bi.

predictive value for postoperative complications (AUC, 0.497). Furthermore, the NRS 2002 (59.03%) and SGA (59.04%) presented the highest sensitivity, and the MST presented the lowest (30.12%) as shown in figure 1 and table 4.

Association of five screening tools with LOS and hospital costs

Table 5 showed the Pearson correlation coefficients between the scores of the five nutritional screening tools and LOS and hospitalisation cost. LOS was poorly correlated with the scores of NRS 2002, MNA-SF and NRI (p<0.05). In addition, the five nutritional screening tools were not correlated with hospitalisation expenses.

DISCUSSION

It is well known that patients with digestive system tumours are often accompanied by different levels of nutritional risk or malnutrition, especially for patients with CRC, most of whom have been in the middle or advanced stage of cancer when diagnosed. A simple and feasible nutritional screening tool with high sensitivity, strong specificity and accurate prediction of postoperative clinical outcomes will be an essential choice. In this study, when patients were admitted to the hospital for the first CRC surgery, the prevalence of nutritional risk for patients ranged from 25.2% to 46.2%, which is diagnosed by five different nutritional screening tools. According to the SGA criteria, 43.5% of patients with CRC were at nutritional risk. This result was consistent with the findings from other studies in similar patient groups,[29–31] which suggested that the results of this study reflect the nutritional risk of patients with CRC in clinical practice. However, our study showed that MNA-SF seemed to identify more patients at nutritional risk than other nutritional risk screening tools, which was consistent with the results of Baek and Heo[32] and Zhang *et al*.[33] In their study, MNA-SF showed high sensitivity compared with nutritional risk screening tools such as NRS 2002 and MUST, which can also explain this finding in our study. The NRI appeared to underestimate the nutritional risk of patients with CRC when compared with NRS 2002, SGA and PG-SGA in recent similar studies.[9 34] A retrospective study[34] of nutritional screening in 80 patients undergoing radical surgery for gastric cancer showed that the probability of nutritional risk measured by NRI at admission was 31% (the cut-off value of NRI score was 100), which was relatively close to our results. Another prospective multicentre study[9] showed that the probability of developing nutritional risk in patients with metastatic CRC measured by NRI was 56% (the cut-off value of NRI score was 97.5), significantly higher than 25.2% in our study. This can be related to the different patient inclusion criteria and different cut-off ranges of the NRI score in different studies. Second, the characteristics of different hospitals and different patient populations may also be the reason for this difference.

In addition, we found that the MNA-SF (κ=0.570, p<0.001) had the best consistency with the SGA through the Kappa consistency test. While the target population in this study was different from Joaquín *et al*,[35] the same conclusion was drawn. The tool of the worst consistency with SGA was the NRI (κ=0.250, p<0.001), which was inverse with the results of a similar previous study (κ=0.564, p<0.001).[15] This is a prospective study from Taiwan, China, with a small sample size (n=45) and a long history. The nutritional risk of patients may have changed dramatically because of regional and temporal differences, which may be one of the reasons for the differing results between

Table 2 Evaluation results and comparative analysis of five nutritional screening tools

Risk of malnutrition	NRS 2002	MNA-SF	MUST	MST	NRI	SGA
Well nourished	58.5%	53.8%	60.5%	69.4%	74.8%	56.5%
Risk of malnutrition	41.5%	46.2%	39.5%	30.6%	25.2%	43.5%
Kappa	0.538	0.570	0.481	0.503	0.250	—
P value	<0.001	<0.001	<0.001	<0.001	<0.001	—
Sensitivity	75.20%	74.10%	73.11%	82.61%	60.00%	—
Specificity	78.98%	82.72%	75.82%	73.68%	65.97%	—
Positive predict value	71.76%	78.63%	66.41%	58.02%	50.38%	—
Negative predict value	81.76%	78.82%	81.18%	90.59%	74.12%	—

MNA-SF, Short Form of Mini Nutritional Assessment; MST, Malnutrition Screening Tool; MUST, Malnutrition Universal Screening Tool; NRI, Nutritional Risk Index; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment.

the two studies. Similarly, in the above study, the MUST showed good agreement with SGA (κ=0.724, p<0.001) insensitivity (96%) and specificity (75%), and was recommended for routine nutritional screening of patients with CRC. In contrast, the concordance between MUST and SGA in our study was low (κ=0.481, p<0.001). In addition to the differences in sample size, region and time mentioned above, the other three nutritional screening tools in our study were not involved in the above study, so the conclusions of the above studies were only for our reference, and the application of other nutritional screening tools in patients with CRC was still considered essential. Moreover, the MST, which has been shown to have good sensitivity in outpatients, chemoradiotherapy patients and hospitalised tumour patients, was observed in patients with CRC with slightly lower sensitivity than those in the above studies.[20 24] This can be explained by the fact that the sensitivity of the MST varies according to the different ranges of MST scores.[20] Therefore, further studies are encouraged to explore the optimal cut-off value for the MST score in patients with CRC.

Nutrition is a significant factor that influences patients' clinical prognosis. Timely identification of patients at nutritional risk is critical to improving clinical outcomes and reducing medical costs. In this study, the incidence of postoperative complications among patients with CRC was 27.6%, similar to the findings of Kwag *et al* (27.0%).[36] The NRS 2002, MNA-SF, MUST and SGA were statistically significant in predicting short-term complications for patients with CRC, respectively. The NRS 2002 had the highest predictive value in predicting postoperative complications (AUC 0.621) and had been proved to be

Table 3 Logistic regression analysis of postoperative complications

Variable	β	SE	Wald	OR (95% CI)	P value
Age ≥60 (years)	0.464	0.330	1.980	1.591 (0.833 to 3.036)	0.159
Monthly income					
<1000 (reference)			2.242		0.691
1000–3000	–0.309	0.376	0.674	0.734 (0.351 to 1.535)	0.412
3001–5000	–0.005	0.403	0.000	0.995 (0.451 to 2.194)	0.990
5001–10000	–0.640	0.569	1.264	0.527 (0.173 to 1.609)	0.261
>10 000	–0.635	1.270	0.250	0.530 (0.044 to 6.388)	0.617
Marital status					
Spinsterhood (reference)			4.251		0.236
Married	20.812	40 192.011	0.000	1092423714 (0.000-.)	1.000
Divorced	19.994	40 192.011	0.000	482462752.0 (0.000-.)	1.000
Widowed	21.549	40 192.011	0.000	2283227783 (0.000-.)	1.000
NRS 2002	0.876	0.425	4.244	2.400 (1.043-5.522)	0.039
SGA	0.457	0.348	1.722	1.579 (0.798-3.125)	0.189
MNA-SF	–0.249	0.479	0.269	0.780 (0.305-1.995)	0.604
MUST	–0.121	0.482	0.063	0.886 (0.344-2.282)	0.803

MNA-SF, Short Form of Mini Nutritional Assessment; MUST, Malnutrition Universal Screening Tool; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment.

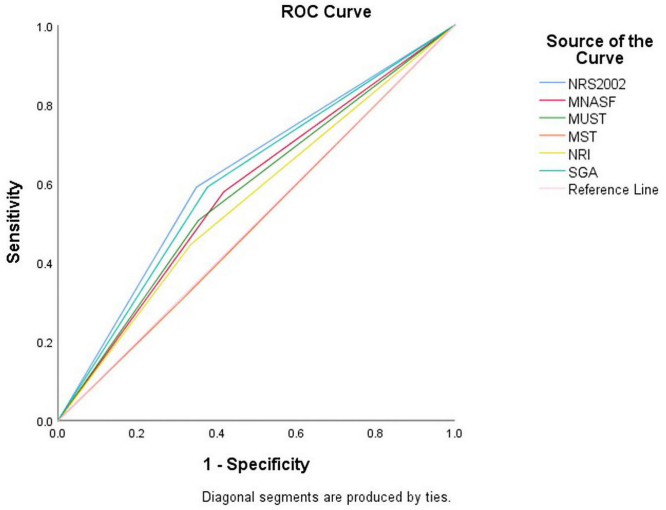

Figure 1 ROC curves of five nutritional screening tools based on postoperative complications. MNA-SF, Short Form of Mini Nutritional Assessment; MST, Malnutrition Screening Tool; MUST, Malnutrition Universal Screening Tool; NRI, Nutritional Risk Index; NRS 2002, Nutritional Risk Screening 2002; ROC, Receiver Operating Characteristic.

an independent risk factor for postoperative complications in patients with CRC, which once again confirmed the results of Kwag *et al*.[36] In this study, the sensitivity of NRS 2002 and SGA was similar in predicting postoperative complications, and the specificity of NRS 2002 was higher than that of SGA, which was consistent with the results of a previous study.[37] However, the sensitivity and specificity of NRS 2002 and SGA in this study were lower than those in the above studies. It may be caused by the evaluation criteria of postoperative complications that were not clearly defined in the above studies, while a clear explanation of the evaluation criterion was provided in this study. The MUST had the lowest predictive value (AUC 0.576), which was slightly different from the results of a previous study.[38] In the previous study, no statistical association was found between the MUST and postoperative complications in patients with CRC,[38] indicating that the predictive value of MUST on postoperative complications of CRC was weak. Nevertheless, the predictive value of MUST in clinical outcomes has yet to be confirmed by more multi-centre, large-sample clinical studies. Similarly, as with other studies, NRI was not sensitive or specific for predicting postoperative complications.[39]

The LOS of patients in this study ranged from 9 to 53 days, with the mean±SD of 19.20±6.69 days. In the previous studies,[38–42] nutritional screening tools such as the NRS 2002, SGA, MUST, NRI and PNI were related to the LOS of patients. However, in this study, only NRS 2002, MNA-SF and NRI were poorly correlated with LOS, none of the tools were associated with hospitalisation costs. This demonstrated that the five nutritional screening tools failed to identify patients with CRC at nutritional risk who may require additional medical care during hospitalisation. It is interesting to note that NRS 2002 and MUST are predictors of hospitalisation costs in inpatients, including those with CRC.[38 43] In our study, however, no correlation had been found between the NRS 2002/MUST and hospitalisation costs. This difference may be explained by the different methods used for calculating hospital costs in different countries. The hospitalisation costs include both direct and indirect hospitalisation costs. Direct hospital costs include additional diagnosis, clinical procedures and additional treatments. While, indirect hospitalisation costs include loss of productivity due to vacation or social costs, including transportation expenses for nursing staff, vacation time for nursing staff or nursing expenses in the community after discharge from the hospital. In this study, researchers only calculated direct hospital costs, which is one of the study's limitations. Moreover, the difference in the MUST interval between the two studies can also be one of the reasons for the difference. Surprisingly, the MST, as the most sensitive and specific nutritional screening tool in our study (based on SGA), did not show predictive value for any postoperative clinical outcomes, reaffirming the results of previous studies despite the different patient groups in the two studies.[21] At present, the research focus of MST is mainly on the verification of this tool, but it is still unknown whether MST can predict the clinical outcomes of patients. Given this, this study applied MST in patients admitted for first surgical treatment of CRC, and to evaluate its predictive value for clinical outcomes.

Table 4 Comparison of the predictive value of five nutritional screening tools for postoperative complications

Screening tools	AUC	Sensitivity	Specificity	PPV	NPV	P value	95% CI
NRS 2002	0.621	59.03	65.14	39.20	80.68	0.001	0.549-0.692
MNA-SF	0.580	57.83	58.26	34.53	78.40	0.031	0.508-0.653
MUST	0.576	50.60	64.68	35.29	77.47	0.040	0.503-0.649
MST	0.497	30.12	69.27	27.17	72.25	0.934	0.424-0.570
NRI	0.555	44.58	66.51	33.64	75.92	0.137	0.482-0.629
SGA	0.607	59.04	62.39	37.40	80.00	0.004	0.535-0.679

AUC, area under the curve; MNA-SF, Short Form of Mini Nutritional Assessment; MST, Malnutrition Screening Tool; MUST, Malnutrition Universal Screening Tool; NPV, negative predictive value; NRI, Nutritional Risk Index; NRS 2002, Nutritional Risk Screening 2002; PPV, positive predictive value; SGA, Subjective Global Assessment.

Table 5 Association of five screening tool scores with LOS and hospital costs

	LOS		Hospitalisation cost	
	r	P value	r	P value
NRS 2002	0.131	0.023	0.092	0.113
MNA-SF	−0.115	0.046	−0.023	0.687
MUST	0.090	0.119	0.007	0.910
MST	0.094	0.102	−0.002	0.972
NRI	−0.187	<0.001	−0.062	0.286
SGA	0.110	0.057	0.087	0.134

LOS, length of hospital stay; MNA-SF, Short Form of Mini Nutritional Assessment; MST, Malnutrition Screening Tool; MUST, Malnutrition Universal Screening Tool; NRI, Nutritional Risk Index; NRS 2002, Nutritional Risk Screening 2002; SGA, Subjective Global Assessment.

LIMITATIONS

Regardless of its strengths, this study has several limitations. First, nutritional screening was conducted only once in hospital and did not monitor the evolution of nutritional risk during the study. If this were the case, we could have explained the relationship between nutritional risk and short-term clinical results in patients with CRC. Second, there is no long-term monitoring and prognostic analysis of clinical outcomes for this study. Finally, this study was carried out on patients from a single medical centre in China, and further prospective multicentric studies are still needed.

CONCLUSION

According to our study, five nutritional screening tools can be used to detect nutritional risk in patients with CRC at admission. Although the MST and MNA-SF showed good sensitivity and specificity in the nutritional risk screening of patients with CRC at admission in our study, we still recommend the NRS 2002 as the best tool for nutritional risk screening. Because of its high efficiency and stability in nutritional screening and prediction of postoperative clinical results in patients with CRC. Of course, additional multicentre studies are needed to explore and test the best nutritional screening tool for patients undergoing CRC surgery.

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Contributors All six authors made substantial contributions to the study and manuscript and met the criteria for authorship that are defined in the author instructions. BX, JS and JG contributed to the acquisition, analysis and interpretation of the data and the drafting of the manuscript. BX, YS, BJ and TD contributed to the design and conduct of the study. YS supervised the project and provided critical revision and final approval of the manuscript. The corresponding author attested that all listed authors meet the authorship criteria and that no one who met the criteria has been omitted. YS as a guarantor accepts full responsibility for the work, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The protocol was reviewed and approved by the ethics committee of the First Hospital of China Medical University (number: (2020)401), and the informed written consent of each patient was obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request.

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