Nutrition Journal

RESEARCH

Open Access

Efficacy of Global Leadership Initiative on Malnutrition as potential cachexia screening tool for patients with solid cancer

Mengmeng Song[1,2,3†], Qi Zhang[1,2,3†], Tong Liu[1,2,3], Meng Tang[1,2,3], Xi Zhang[1,2,3], Guotian Ruan[1,2,3], Xiaowei Zhang[1,2,3], Kangping Zhang[1,2,3], Yizhong Ge[1,2,3,4], Ming Yang[1,2,3], Wei Li[5], Minghua Cong[6], Kunhua Wang[7], Chunhua Song[8] and Hanping Shi[1,2,3*]

Abstract

Purpose: Cachexia has a very high prevalence in patients with cancer, and lacks effective screening tools yet. Global Leadership Initiative on Malnutrition (GLIM) is a novel malnutrition assessment tool, with increased important roles in malnutrition diagnosis for patients with cancer. However, whether GLIM can be used as an effective screening tool remains unknown.

Methods: We performed a multicenter cohort study including 8,478 solid tumor patients from 40 clinical centers throughout China. Cachexia was diagnosed based on the 2011 international cancer cachexia consensus. The receiver operating characteristic curves (ROC) and decision curve analysis (DCA) were developed to determine the efficacy and clinical net benefit of GLIM and Patient-Generated Subjective Global Assessment (PG-SGA) in the detection of cancer cachexia, respectively.

Results: According to the consensus guidelines, 1,441 (17.0%) cancer patients were diagnosed with cachexia among 8,478 patients in the present study. The sensitivity of one-step GLIM and two-step GLIM for detecting cachexia were 100 and 88.8%, respectively, while that of PG-SGA was 86.2%. The accuracies of one-step GLIM and two-step GLIM reached 67.4 and 91.3%, which were higher than that of PG-SGA (63.1%). The area under the curves (AUCs) of one-step GLIM (0.835) and two-step GLIM (0.910) were higher than PG-SGA (0.778) in patients with cancer. The DCA also revealed that two-step GLIM had better clinical effect than PG-SGA between 20-50% threshold probabilities.

Conclusion: GLIM could be used as an effective tool in screening cancer cachexia, two-step GLIM criteria show more accurate while one-step GLIM criteria is more sensitive.

Trial registration: ChiCTR1800020329.

Keywords: Cancer, Cachexia, GLIM, PG-SGA, Screening tools

Introduction

Cachexia, a multifactorial syndrome, is characterized by severe weight loss, sarcopenia, fatigue and compromised appetite [1], which frequently occurs in cancers such as pancreatic, gastrointestinal, head, neck and lung cancer [2]. Cachexia appears in up to 80% of cancer patients, causing at least 20% of cancer-associated deaths [3, 4]. Patients with upper gastrointestinal and

†Mengmeng Song and Qi Zhang contributed equally to this work.

*Correspondence: shihp@ccmu.edu.cn

[1] Department of Gastrointestinal Surgery/Clinical Nutrition, Capital Medical University Affiliated Beijing Shijitan Hospital, No.10 Tieyi Road Haidian Dist, Beijing 100038, China
Full list of author information is available at the end of the article

pancreatic cancer suffered from the highest prevalence (reaching 80%) of cachexia [5], which may result in poor quality of life and survival of patients. However, globally recognized diagnosis criteria for cancer cachexia are still limited.

Patients with malignant tumors were afflicted with malnutrition with an estimated prevalence ranging from 40 to 80% [6]. In fact, cachexia is a special form of disease-related malnutrition which is difficult to reverse through nutrition support compared with common malnutrition [1]. Although there is no globally recognized screening tool for cancer cachexia yet [7], previous studies have tried to explore the availability of nutrition screening or assessment tools for cancer cachexia, including Malnutrition Universal Screening Tool (MUST), Nutritional Risk Screening 2002 (NRS-2002), Malnutrition Screening Tool (MST), Short Nutritional Assessment Questionnaire (SNAQ) [8] and Patient-Generated Subjective Global Assessment (PG-SGA) [9]. Originally, these malnutrition assessment tools were developed to estimate whether a patient has malnutrition or malnutrition risk. NRS-2002, the first step of Global Leadership Initiative on Malnutrition (GLIM) [10], is a nutrition risk screening tool recommended by the European Society for Parenteral and Enteral Nutrition (ESPEN) for adult patients [11]. The MUST was developed to evaluate protein–energy malnutrition and the risk of malnutrition for adults in community population based on three independent indicators. The MST, a simple, quick, and reliable instrument, was developed to detect the risk of malnutrition for patients at admission. The MUST, MST, SNAQ, and NRS-2002 was screening tools for the risk of malnutrition. The PG-SGA was the most authoritative tool for malnutrition diagnosis in patients with cancer [12]. GLIM, a new diagnostic framework for malnutrition in 2016 [13], builds an international consensus around the diagnostic criteria for malnutrition in adults [14]. As a novel guideline, the essential roles of GLIM in malnutrition diagnosis have been proven in many recent studies [14–19]. However, the reliability of GLIM in cancer cachexia assessment and its effectivity compared to other screening tools remain unclear.

It is important to screen and control the progress of cancer cachexia early. The purpose of the present study was to evaluate whether GLIM could be used as a favorable cachexia screening tool, and further to compare the effects of one-step GLIM, two-step GLIM and PG-SGA in the cancer cachexia screening and to explore the clinical significance of GLIM in early screen of cancer cachexia, so as to achieve early prevention and intervention of cachexia, and try to prevent or reduce the occurrence of cachexia.

Material and methods

Study population

Data from the Investigation on Nutrition Status and its Clinical Outcome of Common Cancers (INSCOC) project of China (Asia) were obtained from 40 clinical centers throughout China. The trial was registered at http://www.chictr.org.cn under the registration number ChiCTR1800020329. All participants were followed up via in-person or telephone questionnaires to collect requisite information by specialized staff. The specific inclusion criteria are as follows: (1) $\geq$ 18 years of age; (2) length of hospital stay > 48 h; and (3) diagnosis of one of the following 16 types of locally or metastatic malignant solid tumors: lung cancer, gastric cancer, liver cancer, colorectal cancer, breast cancer, esophageal cancer, cervical cancer, endometrial cancer, nasopharyngeal carcinoma, pancreatic cancer, ovarian cancer, prostate cancer, bladder cancer, brain tumors, biliary tract malignant tumors or gastrointestinal stromal tumors. The exclusion criteria are as follows: (1) organ transplantation; (2) current pregnancy; (3) diagnosis of HIV infection or AIDS; (4) admission to the ICU at the beginning of recruitment; and (5) more than two hospitalizations during the investigation period. Written informed consent was obtained from all participants. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the medical ethics committee of first affiliated hospital of Sun yat-sen University (Medical Research Audit (2013) No. 82).

Data collection

Within the first 48 h after hospital admission, written informed consent was signed by all patients or their legal representatives, and a comprehensive interview of all patients was performed by a dietitian or clinician to obtain recent preoperative nutritional information, including NRS-2002 score, PG-SGA score, and Karnofsky Performance Score (KPS). Laboratory indicators were obtained from routine blood test. Anthropometric measurements included height, body weight, mid-arm circumference (MAC), mid-arm muscle circumference (MAMC), calf circumference (CC, left calf circumference), hand grip strength (HGS) and triceps skinfold thickness (TSF). HGS was measured using a hand dynamometer (Jamar Hand Dynamometer, IL, USA). The handle was adjusted individually to the size of the patient's hand. The percentage of weight loss was calculated by comparing present weight to the corresponding weight over time (six-month interval). BMI was calculated as body weight (kilograms) divided by the square of body height (meters). Considering the effect of weight on HGS, body weight-standardized HGS (HGS/W) was adopted in the study. Having malnutrition risk

were defined as NRS-2002 score ≥ 3, and malnourished patients with cancer was defined as PG-SGA score ≥ 4, respectively.

Diagnosis of malnutrition based on GLIM

The details of GLIM diagnosis criteria were shown in Table S1. The parameters for malnutrition diagnosis and severity grading based on GLIM have been described previously [20]. The one-step GLIM criteria (GLIM-step1) was defined as the malnutrition directly diagnosed by GLIM criteria without nutrition risk screening (performed by NRS-2002). Two-step GLIM criteria (GLIM-step2) was defined as the malnutrition diagnosed by GLIM criteria after nutrition risk screening (performed by NRS-2002) [13]. The evaluation of weight loss was performed for the malnutrition severity grading according to the previous GLIM criteria [20]. Referenced cut-off values of low BMI for malnutrition stage were defined according to a previous study of the Asian population [21, 22]. The quantity of muscle was evaluated by MAMC and CC, and HGS/W represented the muscle function. For each sex, the fifth percentile (p^5) and 15th percentile (p^{15}) of the MAMC, CC and HGS/W were calculated respectively. Values < p^{15} and < p^5 were defined as positive for stage I and stage II malnutrition, respectively [22].

Diagnosis of cancer cachexia

Combined with the international consensus framework [1], cancer cachexia was diagnosed by the following diagnostic criteria: (1). weight loss of > 5% over the past 6 months (in the absence of simple starvation); (2). a BMI of < 18.5 kg/m^2 (based on the criteria of Asia) plus > 2% weight loss; or (3) appendicular skeletal muscle index consistent with sarcopenia (males < 7.0 kg/m^2; females < 5.4 kg/m^2) and any degree of weight loss > 2%. Cancer cachexia was diagnosed if the patients met one at least aforementioned criterion.

Statistical analysis

Mean (standard deviation, SD) and t-test were used to describe and compare continuous variables. Categorical variables were described as numbers (percentages) and analyzed by Pearson Chi-square analysis. Receiver operating characteristic (ROC) curves and decision curves analysis (DCA) were generated to evaluate the efficiency and clinical net benefit of screening tools for detecting cachexia. The ROC curves of different subgroups (tumor types and TNM stage) were performed to evaluate the efficiency of three tools for screening cancer cachexia in different subgroups. Subgroup analysis (age and sex) were performed to detect the efficiency of GLIM and PG-SGA for screening cancer cachexia. In addition, the sensitivity, specificity and accuracy of GLIM and PG-SGA were calculated. All tests were two-sided and $P < 0.05$ was regarded as statistically significant. All statistical analyses were performed by software SPSS version 21 (IBM, Armonk, NY, USA) and R (Version 3.6.3), involving R packages "survminer", "survival", "rmda" and "pROC".

Results

Baseline characteristics

After exclusions of missing data, a total of 8,478 individuals were included in this study. The flow-chart of selection was shown in Fig. 1. Table1 gives the characteristics of the study population with or without cachexia. The mean age of the study population was 56.75 years old, with 4,338 (51.2%) males and 4,140 (48.8%) females. The patients with cancer cachexia were prone to have a significantly lower MAC, TSF, MAMC, CC and KPS than those in non-cachexia group (all $P < 0.001$). Patients with cancer cachexia tended to be younger than 65 years old, male, smoker, alcohol drinker, TNM stage III and IV, with lower albumin and higher NLR (all $P < 0.001$). In addition, compared with patients with cancer cachexia, non-cachexia group had more malnutrition diagnosed by GLIM-step1 and GLIM-step2, and had more anorexia (24.8% Vs. 10.4%) ($P < 0.001$).

Among all patients with cancer, pancreatic cancer was associated with highest cachexia prevalence accounting for 45.0%, followed by gastric cancer (32.5%), esophageal cancer (28.5%), ovarian cancer (23.8%) and colorectal cancer (21.7%), the details were shown in Fig. 2.

The efficacy of GLIM in the screening of cancer cachexia

The sensitivity of the GLIM-step1 and GLIM-step2 for detecting cancer cachexia among all cancer patients was 100% and 88.8% respectively, higher than PG-SGA (86.2%). Both the specificity and accuracy of GLIM-step1 and GLIM-step2 were higher than PG-SGA as shown in Table 2. Figure 3 showed the visualized sensitivities, specificities and accuracies of the GLIM and PG-SGA for detecting cancer cachexia. The AUC of GLIM-step2 was 0.910, which indicated better performance and a stronger capacity to identify patients with cachexia than GLIM-step1 (AUC = 0.835) and PG-SGA (AUC = 0.778) (Fig. 4a). The decision curves of the GLIM and PG-SGA showed that the clinical net benefit of GLIM-step2 was better than that of GLIM-step1 and PG-SGA between threshold probabilities of 20–50% (Fig. 4b). In the subgroup analysis, the AUC of GLIM-step2 was higher than that of GLIM-step1 and PGS-SGA in different cancer types (Supplementary Fig. 1), and TNM stages (Supplementary Fig. 2). There is the same trend in the subgroups of age (age < 65 and age ≥ 65) and BMI (BMI < 24 kg/m^2 and BMI ≥ 24 kg/m^2) (Supplementary Table 2).

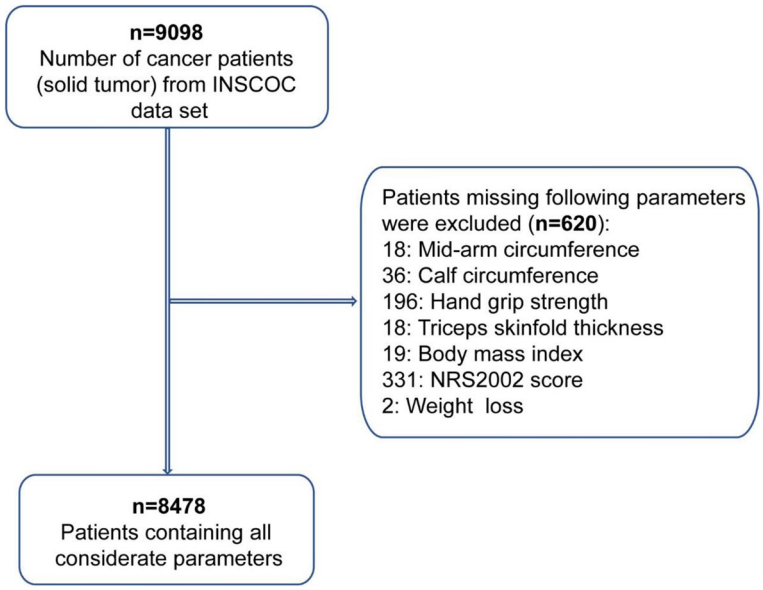

Fig. 1 Flow chart. INSCOC, Investigation on Nutrition Status and its Clinical Outcome of Common Cancers

Discussion

In this multicenter population study, it was proved that GLIM can be used as a good tool for identifying cachexia in patients with cancer. One-step GLIM criteria had higher sensitivity than two-step GLIM criteria, but the specificity and final accuracy of two-step GLIM criteria was better than one-step GLIM criteria. Consequently, it is essential to perform a nutrition risk screening via NRS-2002 or other effective nutrition risk screening tools before the implementation of GLIM. Intriguingly, both one-step GLIM and two-step GLIM have favorable capacity than PG-SGA for detecting cachexia in patients with cancer. All cancer patients should be screened and evaluated for malnutrition risk after admission. Hence, the malnutrition diagnosis criteria, such as GLIM, can be used as a convenient tool for cachexia screening.

The international consensus framework for the definition and classification of cancer cachexia was developed [1] in 2011, declaring that weight loss, BMI and skeletal muscle depletion are the main factors for diagnosing cancer cachexia. Given that there were still no recognized diagnosis criteria of cancer cachexia yet, we used the international consensus framework as criteria of cachexia diagnosis in this research. The cutoff point of BMI in this study was based on the WHO recommended current cutoff points of Asia (18.5 kg/m^2), instead of 20 kg/m^2 in international consensus [23]. The skeletal muscle mass can be quantified with computed axial tomography (CT), magnetic resonance imaging (MRI), dual-energy x-ray absorptiometry, in vivo neutron activation analysis-whole body counting, ultrasound, bioimpedance analysis (BIA), and urinary metabolite markers [24, 25]. These methods were effective for diagnosing cancer cachexia. However, these methods can be costly and complex for cancer cachexia screening. We found that GLIM can be used as a simple screening tool of cancer cachexia, which can help early detection and timely intervention of cancer cachexia, prevent the progress of cachexia and improve the life quality of them.

Several tools for malnutrition assessment have been explored whether they can be used to screen for cachexia in patients with cancer. Among the assessment tools of MUST, NRS-2002, MST, SNAQ, MST was proved to have the greatest ability to detect cancer cachexia among patients with gastric cancer [8], but there is a lack of verification in other types of cancer patients. In addition, PG-SGA was also manifest good detective in cachexia screening for patients with cancer in a recent study [9], lacking comparison with other tools. Our present study assessed the nutritional status of 8,487 cancer patients from multi-centers throughout China by the GLIM and PG-SGA. We found that the GLIM can be a potential screening tool for cancer cachexia, compensating for the insufficiency of cancer types in a previous study. In addition, compared with PG-SGA and other malnutrition assessment tools, the GLIM has fewer items and is easier to perform.

Consistent with previous research [2], this study revealed that pancreatic cancer has a higher incidence of cachexia than other cancers, with gastroesophageal cancer ranked as the second. Interestingly, the prevalence of cachexia in male patients was higher than that in female

Table 1 Baseline characteristics of the study population

Characteristics	All cancer (*n* = 8478)	Non-cachexia (*n* = 7037)	Cachexia (*n* = 1441)	*P*
Age, y, mean (SD)	56.75 (12.05)	56.54 (11.83)	57.77 (13.01)	< 0.001
< 65	6218 (73.30)	5217 (74.10)	1001 (69.50)	< 0.001
≥ 65	2260 (26.70)	1820 (25.90)	440 (30.50)	
Sex, n (%)				
Male	4338 (51.20)	3465 (49.20)	873 (60.60)	< 0.001
Female	4140 (48.80)	3572 (50.80)	568 (39.40)	
BMI, kg/m^2, mean (SD)	22.88 (3.47)	23.57 (3.06)	19.53 (3.39)	< 0.001
TNM, n (%)				
I	1261 (14.90)	1137 (16.20)	124 (8.60)	< 0.001
II	2052 (24.20)	1779 (25.30)	273 (18.90)	
III	2938 (34.70)	2388 (33.90)	550 (38.20)	
IV	2227 (26.30)	1733 (24.60)	494 (34.30)	
Smoke, yes, n (%)	3357 (39.60)	2675 (38.00)	682 (47.30)	< 0.001
Complication, yes, n (%)	2727 (32.2)	2266 (32.2)	461 (32.0)	0.901
Alcohol, yes, n (%)	1569 (18.50)	1222 (17.40)	347 (24.10)	< 0.001
Anorexia, yes, n (%)	1092 (12.90)	734 (10.40)	358 (24.80)	< 0.001
NRS-2002, ≥ 3, n (%)	2217 (26.20)	938 (13.30)	1279 (88.80)	< 0.001
PGSGA, n (%)				
0–3	4304 (50.80)	4105 (58.30)	199 (13.80)	< 0.001
4–8	2594 (30.60)	2093 (29.70)	501 (34.80)	
≥ 9	1580 (18.60)	839 (11.90)	741 (51.40)	
GLIM-step1, n (%)				
Well nourished	4271 (50.40)	4271 (60.70)	0 (0.00)	< 0.001
Moderate malnutrition	2800 (33.00)	1992 (28.30)	808 (56.10)	
Severe malnutrition	1407 (16.60)	774 (11.00)	633 (43.90)	
GLIM-step2, n (%)				
Well nourished	6624 (78.10)	6462 (91.80)	162 (11.20)	< 0.001
Moderate malnutrition	1122 (13.20)	425 (6.00)	697 (48.40)	
Severe malnutrition	732 (8.60)	150 (2.10)	582 (40.40)	
KPS, Mean (SD)	87.09 (12.79)	88.12 (11.69)	82.04 (16.28)	< 0.001
Albumin (g/L), Mean (SD)	39.53 (10.49)	39.89 (8.52)	37.78 (17.01)	< 0.001
≥ 35	6883 (81.20)	5924 (84.20)	959 (66.60)	< 0.001
< 35	1595 (18.80)	1113 (15.80)	482 (33.40)	
NLR, Mean (SD)	3.70 (7.15)	3.5 (6.64)	4.69 (9.19)	< 0.001
MAC (cm), Mean (SD)	26.58 (3.55)	27.08 (3.31)	24.16 (3.69)	< 0.001
TSF (mm), Mean (SD)	16.90 (8.01)	17.79 (7.89)	12.59 (7.19)	< 0.001
MAMC (cm), Mean (SD)	20.83 (3.43)	21.03 (3.42)	19.88 (3.27)	< 0.001
CC (cm), Mean (SD)	33.23 (3.91)	33.72 (3.68)	30.80 (4.07)	< 0.001

All of other cancer were solid neoplasms, including bladder cancer, prostate cancer, endometrial cancer, brain malignant tumor, gastric stromal tumor and biliary tract cancer

SD Standard deviation, *BMI* Body mass index, *NRS2002* the Nutritional Risk Screening 2002, *PG-SGA* Patient-Generated Subjective Global Assessment, *GLIM* the Global Leadership Initiative on Malnutrition, *GLIM-step1* One-step GLIM criteria, *GLIM-step2* Two-step GLIM criteria. One-step GLIM criteria and two-step GLIM criteria represented different GLIM criteria with or without nutrition risk screening by NRS-2002, respectively, *KPS* Karnofsky Score, *NLR* Neutrophil-to-lymphocyte ratio, *MAC* Mid-arm circumference, *TSF* Triceps skinfold thickness, *MAMC* Mid-arm muscle circumference, *CC* Calf circumference (left calf)

patients in this study. This is presumably because the incidences of pancreatic cancer, stomach cancer, colorectal cancer and esophageal cancer were higher in males than in females [26, 27], and the largest number of cachexia diagnoses occurred in these several cancer types [2]. The prevalence of cachexia increased with the progression of TNM stage I-IV in this study. A previous study reported that cachexia can also occur in curable cancers and may

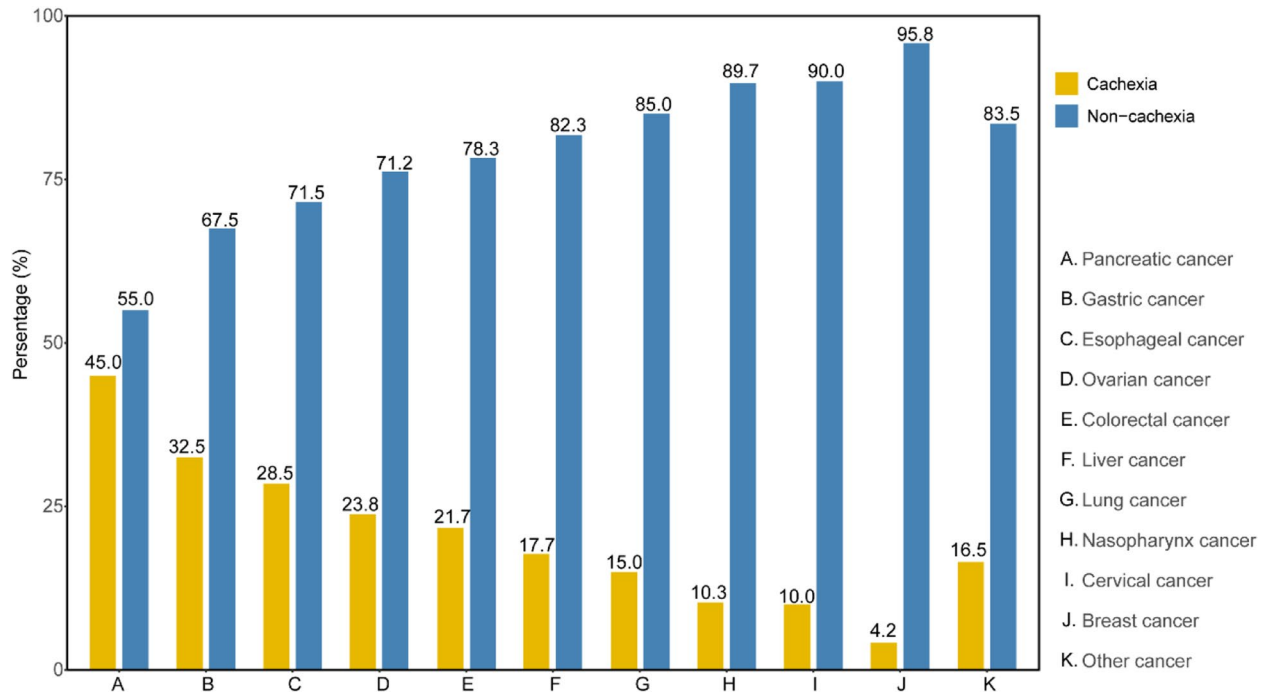

Fig. 2 The cachexia prevalence in different types of cancer. Women cancer included breast cancer, ovarian cancer and cervical cancer; all of other cancers included bladder cancer, prostate cancer, endometrial cancer, brain malignant tumor, gastric stromal tumor and biliary tract cancer

Table 2 Sensitivity and specificity of the GLIM and PG-SGA for detecting cancer cachexia

	Cachexia ($n=1441$)	No Cachexia ($n=7037$)	Sensitivity (%)	Specificity (%)	Accuracy (%)	AUC
GLIM-step1			100	60.7	67.4	0.835
Well nourished	0	4271	-	-		-
Malnutrition	1441	2766	-	-		-
GLIM-step2			88.8	91.8	91.3	0.910
Well nourished	162	6462	-	-		-
Malnutrition	1279	575	-	-		-
PG-SGA			86.2	58.3	63.1	0.778
Well nourished	199	4105	-	-		-
Malnutrition	1242	2932	-	-		-

AUC Area Under the ROC Curve, *GLIM* the Global Leadership Initiative on Malnutrition, *GLIM-step1* One-step GLIM criteria, *GLIM-step2* Two-step GLIM criteria. One-step GLIM criteria and two-step GLIM criteria represented different GLIM criteria with or without nutrition risk screening by NRS-2002, respectively; *PG-SGA* Patient-Generated Subjective Global Assessment, *PG-SGA* Well nourished (Score < 4), Malnutrition (Score ≥ 4)

be reversed by effective treatment [28]. Therefore, early and accurate screening of cancer cachexia is important for effective nutritional intervention and anticancer treatment response. The prevalence of cachexia in all solid cancer patients in our study was 17.0%, lower than the incidence of cancer cachexia in previous study [29], probably because many types of cancer patients were enrolled in this study, including breast cancer and nasopharynx cancer, which have a relatively low prevalence of cachexia. The process of GLIM-diagnosed malnutrition is more stringent than the diagnosis with PG-SGA, thus the number of cancer patients with PG-SGA-diagnosed malnutrition was greater than that of patients with GLIM-diagnosed malnutrition. In addition, compared with the sensitivity and specificity, the clinical net benefit is more essential for nutritional intervention for cancer cachexia. The DCAs revealed that the two-step GLIM had better clinical net benefit than one-step GLIM and PG-SGA.

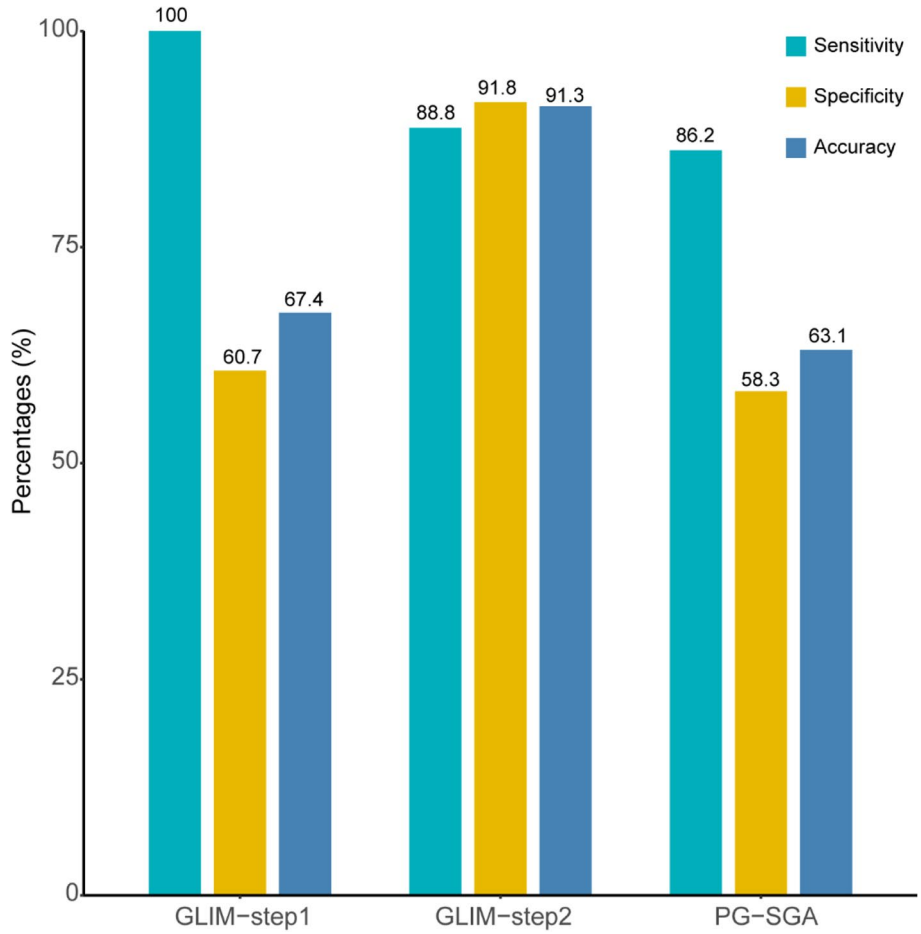

Fig. 3 The sensitivity and specificity of GLIM and PG-SGA for detecting cancer cachexia. GLIM, Global Leadership Initiative on Malnutrition; PG-SGA, Patient-Generated Subjective Global Assessment. GLIM-step1: one-step GLIM criteria; GLIM-step2; two-step GLIM criteria. Two-step GLIM criteria and one-step GLIM criteria represented different GLIM criteria with or without nutrition risk screening by NRS-2002, respectively

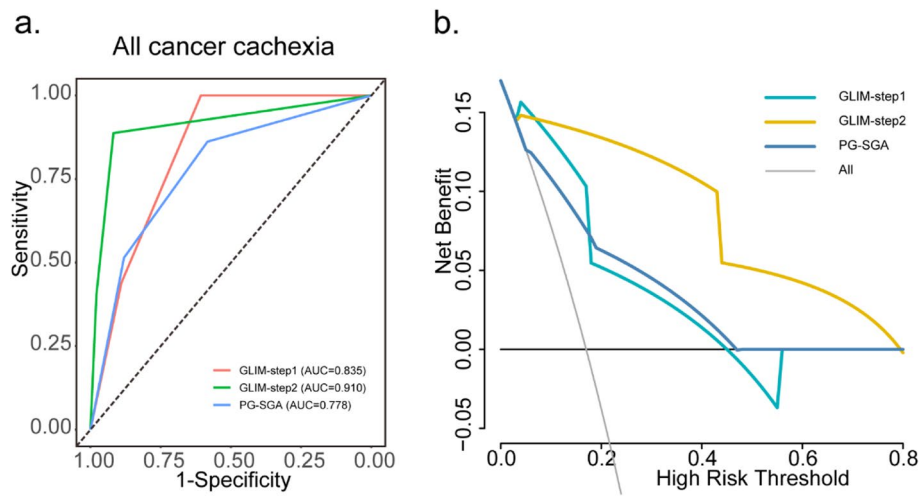

Fig. 4 The ROCs and decision curve in predicting cachexia assessed by the PG-SGA and GLIM. **a** The ROCs of one-step, two-step GLIM criteria and PG-SGA for predicting all cancers patients with cachexia; **b** The decision curves for GLIM and PG-SGA to predict the correct diagnosis of cachexia in cancer patients. AUC, Area Under the Curve; GLIM, Global Leadership Initiative on Malnutrition; PG-SGA, Patient-Generated Subjective Global Assessment

There are several limitations in this study. Firstly, studying population barring hematologic tumor may generate selection bias, leading to the conclusion of our study was not suitable for hematologic tumor. Secondly, only two nutritional screening tools were involved in the comparison. Thus, GLIM needs to be verified and compared with more screening tools in future research.

Conclusion

Our results demonstrated that GLIM is a potentially simple cachexia screening tool in patients with cancer. This finding may facilitate early detection and effective management of cancer cachexia in clinical practice. Further study in a larger population from different areas should be performed to validate the performance of GLIM in the cancer cachexia screening.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12937-022-00829-2.

Additional file 1. Supplementary Figure. The ROC curves in predicting cachexia in different cancers assessed by the PG-SGA and GLIM. (a-i). The ROCs of GLIM, PG-SGA for pancreatic cancer, gastric cancer, esophageal cancer, and colorectal cancer, lung cancer, liver cancer, nasopharynx cancer, women cancer and other cancer, respectively. Women cancer included breast cancer, ovarian cancer and cervical cancer; all of other cancers included bladder cancer, prostate cancer, endometrial cancer, brain malignant tumor, gastric stromal tumor and biliary tract cancer. **Supplementary Figure.** The ROCs of GLIM, PG-SGA for detecting cachexia in cancer patients with different TNM stages. (a-d). The ROCs of one-step GLIM, two-step GLIM and PG-SGA for detecting cachexia in patients with TNM stage I, stage II, stage III and stage IV, respectively.

Additional file 2. Supplementary Table. Phenotypic and etiologic criteria the diagnosis of malnutrition of GLIM. **Supplementary Table.** Subgroup analysis of the GLIM and PG-SGA for detecting cancer cachexia.

Acknowledgements

The authors would like to thank the INSCOC project members for their substantial work on data collecting and follow-up.

Authors' contributions

All authors contributed to the study conception and design. Conceptualization: Hanping Shi; Methodology: Mengmeng Song, Qi Zhang, Yizhong Ge; Formal analysis and investigation: Mengmeng Song, Qi Zhang, Tong Liu, Xi Zhang, Meng Tang, Guotian Ruan, Xiangrui Li, Kangping Zhang, Ming Yang, Kunhua Wang, Wei Li; Writing—original draft preparation: Mengmeng Song; Writing—review and editing: Mengmeng Song, Hanping Shi, Chunhua Song, Tong Liu; Funding acquisition: Hanping Shi; Resources: Hanping Shi. The author(s) read and approved the final manuscript.

Funding

This work was supported by National Key Research and Development Program to Dr. Hanping Shi (No. 2022YFC2009600).

Availability of data and material

Not applicable.

Declarations

Ethics approval and consent to participate

The study was conducted in line with the Helsinki declaration; its design was approved by the local Ethics Committees of all participant hospitals. All patients signed an informed consent form before participating in the study. The trial was registered at http://www.chictr.org.cn with registration number ChiCTR1800020329. All patients provided written consent for the scientific use of their data.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Gastrointestinal Surgery/Clinical Nutrition, Capital Medical University Affiliated Beijing Shijitan Hospital, No.10 Tieyi Road Haidian Dist, Beijing 100038, China. [2]Key Laboratory of Cancer FSMP for State Market Regulation, Beijing 100038, China. [3]Beijing International Science and Technology Cooperation Base for Cancer Metabolism and Nutrition, Beijing 100038, China. [4]The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Wenzhou 325000, China. [5]Cancer Center of the First Hospital of Jilin University, Changchun, Jilin 130021, China. [6]Department of Comprehensive Oncology, National Cancer Center/National Clinical Research Center for Cancer/Cancer Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China. [7]Yunnan University, Kunming 650091, China. [8]Department of Epidemiology and Statistics, Henan Key Laboratory of Tumor Epidemiology College of Public Health, Zhengzhou University, Zhengzhou 450001, Henan, China.

Received: 15 February 2022 Accepted: 28 November 2022
Published online: 07 December 2022

References

1. Fearon K, Strasser F, Anker SD, Bosaeus I, Bruera E, Fainsinger RL, Jatoi A, Loprinzi C, MacDonald N, Mantovani G, et al. Definition and classification of cancer cachexia: an international consensus. Lancet Oncol. 2011;12(5):489–95.
2. Baracos VE, Martin L, Korc M, Guttridge DC, Fearon KCH. Cancer-associated cachexia. Nat Rev Dis Primers. 2018;4:17105.
3. Tisdale MJ. Cachexia in cancer patients. Nat Rev Cancer. 2002;2(11):862–71.
4. Biswas AK, Acharyya S. Understanding cachexia in the context of metastatic progression. Nat Rev Cancer. 2020;20(5):274–84.
5. Henderson SE, Makhijani N, Jemal A. Pancreatic cancer-induced cachexia and relevant mouse models. Pancreas. 2018;47(8):937–45.
6. Arends J, Baracos V, Bertz H, Bozzetti F, Calder PC, Deutz NEP, Erickson N, Laviano A, Lisanti MP, Lobo DN, et al. ESPEN expert group recommendations for action against cancer-related malnutrition. Clin Nutr. 2017;36(5):1187–96.
7. Sanchez-Rodriguez D, Annweiler C, Marco E, Hope S, Piotrowicz K, Surquin M, Ranhoff A, Van Den Noortgate N. European Academy for medicine of ageing session participants' report on malnutrition assessment and diagnostic methods; an international survey. Clin Nutr ESPEN. 2020;35:75–80.
8. Chen XY, Zhang XZ, Ma BW, Li B, Zhou DL, Liu ZC, Chen XL, Shen X, Yu Z, Zhuang CL. A comparison of four common malnutrition risk screening tools for detecting cachexia in patients with curable gastric cancer. Nutrition. 2020;70:110498. https://doi.org/10.1016/j.nut.2019.04.009. Epub 2019 Apr 26.
9. Cong M, Song C, Xu H, Song C, Wang C, Fu Z, Ba Y, Wu J, Xie C, Chen G, et al. The patient-generated subjective global assessment is a promising screening tool for cancer cachexia. BMJ Support Palliat Care. 2020;12(e1):e39–e46.
10. Van Bokhorst-de van der Schueren MA, Guaitoli PR, Jansma EP, de Vet HC. Nutrition screening tools: does one size fit all? A systematic review of screening tools for the hospital setting. Clin Nutr. 2014;33(1):39–58

11. Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. ESPEN guidelines for nutrition screening 2002. Clin Nutr. 2003;22(4):415–21.
12. Laky B, Janda M, Kondalsamy-Chennakesavan S, Cleghorn G, Obermair A. Pretreatment malnutrition and quality of life - association with prolonged length of hospital stay among patients with gynecological cancer: a cohort study. BMC Cancer. 2010;10:232.
13. Cederholm T, Jensen GL, Correia M, Gonzalez MC, Fukushima R, Higashiguchi T, Baptista G, Barazzoni R, Blaauw R, Coats AJS, et al. GLIM criteria for the diagnosis of malnutrition - a consensus report from the global clinical nutrition community. J Cachexia Sarcopenia Muscle. 2019;10(1):207–17.
14. Allard JP, Keller H, Gramlich L, Jeejeebhoy KN, Laporte M, Duerksen DR. GLIM criteria has fair sensitivity and specificity for diagnosing malnutrition when using SGA as comparator. Clin Nutr. 2020;39(9):2771–7.
15. Pironi L, Sasdelli AS, Ravaioli F, Baracco B, Battaiola C, Bocedi G, Brodosi L, Leoni L, Mari GA, Musio A. Malnutrition and nutritional therapy in patients with SARS-CoV-2 disease. Clin Nutr. 2020;40(3):1330–7.
16. Rodríguez-Mañas L, Rodríguez-Sánchez B, Carnicero JA, Rueda R, García-Garcia FJ, Pereira SL, Sulo S. Impact of nutritional status according to GLIM criteria on the risk of incident frailty and mortality in community-dwelling older adults. Clin Nutr. 2020;40(3):1192–8.
17. Zhang X, Tang M, Zhang Q, Zhang KP, Guo ZQ, Xu HX, Yuan KT, Yu M, Braga M, Cederholm T, et al. The GLIM criteria as an effective tool for nutrition assessment and survival prediction in older adult cancer patients. Clin Nutr. 2021;40(3):1224–32.
18. Sanchez-Rodriguez D, Locquet M, Reginster JY, Cavalier E, Bruyère O, Beaudart C. Mortality in malnourished older adults diagnosed by ESPEN and GLIM criteria in the SarcoPhAge study. J Cachexia Sarcopenia Muscle. 2020;11(5):1200–11.
19. Contreras-Bolívar V, Sánchez-Torralvo FJ, Ruiz-Vico M, González-Almendros I, Barrios M, Padín S, Alba E, Olveira G. GLIM criteria using hand grip strength adequately predict six-month mortality in cancer in patients. Nutrients. 2019;11(9):2043.
20. Cederholm T, Jensen GL, Correia M, Gonzalez MC, Fukushima R, Higashiguchi T, Baptista G, Barazzoni R, Blaauw R, Coats A, et al. GLIM criteria for the diagnosis of malnutrition - a consensus report from the global clinical nutrition community. Clin Nutr. 2019;38(1):1–9.
21. Maeda K, Ishida Y, Nonogaki T, Mori N. Reference body mass index values and the prevalence of malnutrition according to the global leadership initiative on malnutrition criteria. Clin Nutr. 2020;39(1):180–4.
22. Yin L, Lin X, Li N, Zhang M, He X, Liu J, Kang J, Chen X, Wang C, Wang X, et al. Evaluation of the global leadership initiative on malnutrition criteria using different muscle mass indices for diagnosing malnutrition and predicting survival in lung cancer patients. JPEN J Parenter Enteral Nutr. 2021;45(3):607–17.
23. Consultation We. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157–63.
24. Poulia KA, Sarantis P, Antoniadou D, Koustas E, Papadimitropoulou A, Papavassiliou AG, Karamouzis MV. Pancreatic cancer and cachexia-metabolic mechanisms and novel insights. Nutrients. 2020;12(6):1543.
25. Lee RC, Wang ZMand Heymsfield SB,. Skeletal muscle mass and aging: regional and whole-body measurement methods. Can J Appl Physiol. 2001;26(1):102–22.
26. Siegel RL, Miller KD, Jemal A. Cancer statistics 2020. CA: Cancer J Clin. 2020;70(1):7–30.
27. Siegel RL, Miller KD, Goding Sauer A, Fedewa SA, Butterly LF, Anderson JC, Cercek A, Smith RA, Jemal A. Colorectal cancer statistics, 2020. CA Cancer J Clin. 2020;70(3):145–64.
28. Arends J, Bachmann P, Baracos V, Barthelemy N, Bertz H, Bozzetti F, Fearon K, Hütterer E, Isenring E, Kaasa S, et al. ESPEN guidelines on nutrition in cancer patients. Clin Nutr. 2017;36(1):11–48.
29. von Haehling S, Anker MSand Anker SD,. Prevalence and clinical impact of cachexia in chronic illness in Europe, USA, and Japan: facts and numbers update 2016. J Cachexia Sarcopenia Muscle. 2016;7(5):507–9.

Publisher's Note