Prognostic value of preoperative modified Glasgow prognostic score in predicting overall survival in breast cancer patients: A retrospective cohort study

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Abstract. The modified Glasgow prognostic score (mGPS), based on C-reactive protein and albumin levels, is an inflammation-based prognostic tool used in various cancers. However, related research in breast cancer is limited. The present study evaluated the prognostic value of the preoperative mGPS in predicting overall survival (OS) of patients with breast cancer undergoing surgery. A retrospective cohort study was conducted involving 300 patients with breast cancer with up to 10 years of follow-up. Patients were categorized into three groups based on mGPS scores of 0, 1 and 2, and their clinical and pathological data were collected. Kaplan-Meier survival analysis and Cox proportional hazards models were used to assess survival outcomes and identify risk factors associated with higher mGPS scores. A prognostic nomogram was developed based on multivariate analysis to predict 5- and 10-year OS. Patients with high mGPS scores showed significantly poor survival outcomes. The 5- and 10-year survival rates for mGPS 0, 1 and 2 were 80, 70 and 55%, and 71, 55 and 22%, respectively (P<0.001). Multivariate Cox analysis identified the mGPS, age, smoking, PAM50 and TNM stage as independent predictors of OS. The nomogram based on the mGPS demonstrated good predictive accuracy (concordance index: 0.81) and calibration. The preoperative mGPS is an independent prognostic factor for OS of patients with breast cancer. It is a simple, cost-effective tool that can aid in risk stratification and guide treatment strategies. Further validation in larger cohorts is recommended.

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Abbreviations: mGPS, modified Glasgow prognostic score; CRP, C-reactive protein; Alb, albumin; OS, overall survival; TNM, tumor-node-metastasis; PAM50, 50-gene intrinsic subtype classifier; ER, estrogen receptor; PR, progesterone receptor; HER2, human epidermal growth factor receptor 2; TNBC, triple-negative breast cancer; HR, hazard ratio; OR, odds ratio; C-index, concordance index; CI, confidence interval; BMI, body mass index

Key words: breast cancer, modified Glasgow prognostic score, overall survival, prognostic biomarker, nomogram

Introduction

Breast cancer is the most commonly diagnosed cancer among women worldwide and remains a leading cause of cancer-related mortality. Despite advancements in early detection and treatment strategies, the prognosis of breast cancer varies significantly due to its heterogeneous nature and the complex interactions between tumor biology and the host immune response (1). Identifying reliable prognostic factors is essential for personalized treatment and management, which can improve survival outcomes and the quality of life of patients with breast cancer (2).

Inflammation has a crucial role in cancer development, progression and response to treatment (3). The modified Glasgow prognostic score (mGPS), a systemic inflammation-based scoring system, has emerged as a valuable prognostic tool for various cancers (4). The mGPS is derived from two widely accessible biomarkers: C-reactive protein (CRP) and albumin (Alb) levels. A score of 0 indicates a low mGPS, representing normal CRP (≤10 mg/l) and Alb (≥35 g/l) levels. Scores of 1 and 2 correspond to high mGPS, indicating elevated CRP levels (>10 mg/l) with normal or decreased Alb levels, respectively. This simple, non-invasive scoring system has been validated in various cancer types, including prostate, gynecological, lung and colorectal cancers, showing a consistent association with poor survival outcomes (5-10). However, its prognostic utility in breast cancer remains underexplored.

Recent studies suggest that systemic inflammation influences the tumor microenvironment and may modulate immune surveillance and therapeutic response. Elevated CRP levels are indicative of chronic inflammation, while hypoalbuminemia reflects malnutrition and systemic inflammation, both of which can impair the host's ability to mount an effective anti-tumor response (11-14). Given that breast cancer subtypes, such as triple-negative breast cancer (TNBC), have distinct molecular profiles and immune characteristics, understanding the predictive value of mGPS across these subtypes is crucial for its clinical applicability.

In breast cancer, several established prognostic factors include tumor size, lymph node status, histological grade, hormone receptor status, human epidermal growth factor receptor 2 (HER2) status and 50-gene intrinsic subtype classifier (PAM50) subtypes (15-17). However, these factors primarily focus on tumor biology and do not account for the systemic inflammatory response. By integrating mGPS with these traditional prognostic markers, it is possible to develop a more comprehensive risk stratification model that reflects both tumor and host-related factors. This approach may offer better predictive accuracy for OS and aid in tailoring therapeutic interventions for different patient groups.

The current study aims to evaluate the prognostic value of the preoperative mGPS in patients with breast cancer undergoing surgery. A retrospective analysis of 300 patients with breast cancer who underwent surgery and were followed for up to 10 years was conducted. The association between preoperative mGPS and long-term survival outcomes was assessed using a variety of statistical methods, including Kaplan-Meier survival analysis, logistic regression and Cox proportional hazards models. In addition, a nomogram based on significant factors identified in a multivariate analysis was constructed to predict 5- and 10-year OS. By analyzing the impact of mGPS on breast cancer prognosis, the present study aimed to provide insights into its potential role as an independent predictor of survival. This study also seeks to establish whether mGPS, when combined with established clinical and pathological factors, can improve risk stratification and guide personalized treatment planning. The findings of this study may help integrate mGPS into routine clinical practice as a simple, accessible and effective prognostic tool for patients with breast cancer.

Patients and methods

Patients. The present study is a retrospective cohort analysis conducted on patients with breast cancer who underwent surgical treatment at the Affiliated Cancer Hospital of Xinjiang Medical University (Urumqi, China) from January 2013 to January 2014. A total of 300 patients were included based on the following criteria: i) Histologically confirmed breast cancer; ii) available preoperative CRP and Alb levels for mGPS calculation; iii) complete clinicopathological data; and iv) a follow-up period of at least five years. Patients with concurrent inflammatory diseases or autoimmune conditions, or those receiving immunosuppressive therapy were excluded to minimize confounding factors that may influence systemic inflammation levels. The inclusion of 300 consecutive patients within this one-year period was based on the hospital's annual surgical caseload for breast cancer during this timeframe. Given the large number of breast cancer surgeries conducted at the hospital annually, this cohort provided an adequate sample size to conduct meaningful survival analysis while reflecting the real-world clinical setting. This period allowed for comprehensive follow-up data collection (up to 10 years) and ensured consistency in treatment protocols during that time. Therefore, this cohort size and timeframe were appropriate to investigate the prognostic value of preoperative mGPS in patients with breast cancer. Among the enrolled patients, a subset of patients with stage IV breast cancer was included. Typically, patients with stage IV breast cancer, due to distant metastasis, are not candidates for curative surgery. However, certain patients with stage IV in this study underwent palliative surgery, primarily to alleviate symptoms or control the primary tumor. These surgeries were conducted in conjunction with other treatments, such as chemotherapy, targeted therapy or endocrine therapy. The surgeries were not aimed at curing the disease but at improving the patients' quality of life or addressing local complications caused by the primary tumor. All patients, including those with stage IV disease, underwent comprehensive clinical evaluation prior to surgery. The decision to proceed with surgery was made by a multidisciplinary team, considering the patient's overall health, response to previous treatments and symptom burden. The inclusion of patients with stage IV in the present study was intended to explore the OS and prognostic factors associated with breast cancer, with a focus on evaluating the role of the mGPS as a prognostic tool. It is acknowledged that patients with stage IV typically have a shorter survival period, but their inclusion helps assess the prognostic predictive value of the mGPS across different stages of breast cancer.

Data collection. Clinical and pathological data were retrieved from the electronic medical records of each patient. Collected variables included age, body mass index (BMI), smoking status, alcohol consumption, diabetes status, hypertension, family history of breast cancer, TNM stage (18) and PAM50 molecular subtype (19). Treatment modalities, including endocrine therapy, targeted therapy, chemotherapy and immunotherapy, were also documented. All patients provided informed consent prior to data collection and the study was approved by the Ethics Committee of the Affiliated Cancer Hospital of Xinjiang Medical University (Urumqi, China; approval no. K-2024056) in accordance with the Declaration of Helsinki.

mGPS calculation. The mGPS was calculated based on preoperative CRP and serum Alb levels. A score of 0 was assigned if CRP levels were ≤10 mg/l and Alb levels were ≥35 g/l. A score of 1 was assigned if CRP levels were >10 mg/l with Alb levels ≥35 g/l. A score of 2 was assigned if CRP levels were >10 mg/l and Alb levels <35 g/l. Patients were stratified into three groups based on their mGPS: mGPS 0 (108 patients), mGPS 1 (120 patients) and mGPS 2 (72 patients), as shown in Table I. This stratification allowed for comparison of clinical outcomes across different mGPS categories.

Statistical analysis. All statistical analyses were conducted using SPSS software (version 29.0; IBM Corp.) and R software (version 4.0.3; R Foundation for Statistical Computing).

Table I. Distribution of patients with breast cancer based on mGPS.

mGPS	CRP, mg/l	Alb, g/l	Number
Low (0)	≤10	≥35	108
High			
1	>10	≥35	120
2	>10	<35	72

mGPS, modified Glasgow prognostic score; CRP, C-reactive protein; Alb, albumin.

P<0.05 was considered to indicate statistical significance. Baseline characteristics: Descriptive statistics were used to summarize the clinical and pathological characteristics of the study population. Continuous variables (e.g., age, BMI) were expressed as the mean ± standard deviation and compared across mGPS groups using one-way ANOVA, after confirming the normality of the data using the Shapiro-Wilk test. If the data did not meet the normality assumption, the Kruskal-Wallis H-test was used as an alternative. For post-hoc analysis, Tukey's Honestly Significant Difference test was applied to identify specific group differences. Categorical variables (e.g., smoking, drinking, TNM stage, PAM50 subtype) were expressed as frequencies and percentages and compared using the Chi-square test or Fisher's exact test, as appropriate. Kaplan-Meier survival analysis: OS was defined as the time from the date of surgery to the date of death from any cause or the last follow-up. Patients lost to follow-up were censored at the time of the last available follow-up. Censoring refers to the inclusion of individuals who did not experience the event of interest (death) by the end of the study period or at the time they were lost to follow-up. Kaplan-Meier survival curves were generated to evaluate the OS of patients in the mGPS 0, 1 and 2 groups. The log-rank test was applied to compare survival differences among the groups. The 5- and 10-year survival rates were recorded for each mGPS category. Logistic regression analysis: To identify factors associated with higher mGPS scores, a univariate logistic regression analysis was performed for each clinical and pathological variable, including age, BMI, smoking status, alcohol consumption, diabetes, hypertension, TNM stage and PAM50 subtype. Variables with a P<0.05 in the univariate analysis were subsequently included in a multivariate logistic regression model. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using logistic regression analysis to determine the independent risk factors for higher mGPS scores, adjusting for potential confounders such as age, sex, disease stage, and treatment modalities. Cox proportional hazards regression analysis: Univariate and multivariate Cox proportional hazards regression models were used to assess the association between mGPS and OS. Clinical and pathological variables and mGPS scores were first analyzed individually to determine their hazard ratios (HRs) for OS. Variables with P<0.05 in the univariate analysis were included in the multivariate analysis. The multivariate model adjusted for potential confounders to identify independent predictors of OS. Nomogram and calibration curve: A nomogram was constructed based on the results of the multivariate Cox regression analysis to predict the 5- and 10-year OS of patients. The nomogram incorporated the most significant prognostic factors, including age, smoking status, TNM stage, PAM50 subtype and mGPS score. The nomogram's predictive accuracy was evaluated using Harrell's C-index. Calibration curves were plotted to assess the agreement between predicted survival probabilities and observed outcomes using bootstrapped resampling (1,000 repetitions) for internal validation.

Results

Patient characteristics and differences across mGPS groups. A total of 300 patients with breast cancer were included in the present study. The mean age of the patients was 51.3 years (range, 34-78 years). All patients were female. Patients were categorized into three groups based on their preoperative mGPS: mGPS 0 (n=108), mGPS 1 (n=120) and mGPS 2 (n=72). The baseline characteristics of the patients are summarized in Table II. Significant differences were observed among the three mGPS groups in terms of age (P<0.001), BMI (P=0.011), smoking status (P<0.001), alcohol consumption (P=0.027), diabetes (P=0.026), TNM stage (P=0.001) and PAM50 molecular subtype (P=0.047). Specifically, higher mGPS scores were associated with older age, higher BMI, smoking and drinking history, advanced TNM stage and TNBC subtype. No significant differences were found for hypertension, family history of breast cancer or treatment modalities (endocrine therapy, targeted therapy, chemotherapy and immunotherapy) (P>0.05 for all).

High mGPS scores are associated with poor survival outcomes. The Kaplan-Meier survival curves for the three mGPS groups are shown in Fig. 1. The 5-year survival rates were 80, 70 and 55% for the mGPS 0, mGPS 1 and mGPS 2 groups, respectively. The 10-year survival rates were 71, 55 and 22% for these groups. The log-rank test revealed a significant difference in OS among the three groups (P<0.001). Further pairwise comparisons showed significant differences between the following groups: mGPS 0 vs. mGPS 1 (P<0.001), mGPS 1 vs. mGPS 2 (P=0.025) and mGPS 0 vs. mGPS 2 (P<0.001). Patients with higher mGPS scores had significantly poorer survival outcomes compared to those with lower scores. Specifically, the mGPS 2 group demonstrated the worst survival rates, highlighting the association between higher mGPS scores and reduced survival.

Risk factors associated with high mGPS scores. To identify clinical and pathological factors associated with high mGPS scores, logistic regression analysis was performed. In the univariate analysis (Table III), factors significantly associated with increased mGPS scores included age ≥65 years (OR: 2.836, 95% CI: 1.783-4.545, P<0.001), smoking (OR: 3.214, 95% CI: 1.948-5.267, P<0.001), drinking (OR: 2.180, 95% CI: 1.355-3.486, P=0.002), TNM stage III (OR: 3.145, 95% CI: 1.358-5.765, P<0.001), TNM stage IV (OR: 4.832, 95% CI: 3.227-8.906, P<0.001) and TNBC subtype (OR: 3.123, 95% CI: 1.858-5.251, P<0.001). These variables were included in the multivariate logistic regression model, which confirmed

Table II. Baseline characteristics of patients with breast cancer stratified by mGPS scores.

Characteristic	Total (n=300)	Low mGPS 0 (n=108)	High mGPS 1 (n=120)	High mGPS 2 (n=72)	P-value
Age, years					<0.001
<65	186	84	67	35	
≥65	114	24	53	37	
BMI, kg/m^2					0.011
≤18.5	83	24	29	30	
>18.5, <25	142	61	54	27	
≥25	75	23	37	15	
Smoking	167	42	75	50	<0.001
Drinking	208	65	87	56	0.027
Diabetes	74	15	37	22	0.026
Hypertension	136	43	58	35	0.354
Family history	45	13	22	10	0.395
TNM stage					0.001
I	159	72	63	24	
II	94	28	36	30	
III	35	7	15	13	
IV	12	1	6	5	
PAM50					0.047
ER+ or PR+	151	62	56	33	
HER2+	82	29	38	15	
TNBC	67	17	26	24	
Treatment					
Endocrine therapy	155	62	59	34	0.317
Targeted therapy	84	30	38	16	0.369
Chemotherapy	102	36	37	29	0.402
Immunotherapy	44	14	21	9	0.525

mGPS, modified Glasgow prognostic score; TNM, tumor-node-metastasis; BMI, body mass index; PAM50, 50-gene intrinsic subtype classifier; ER, estrogen receptor; PR, progesterone receptor; TNBC, triple-negative breast cancer; HER2, human EGFR 2.

that age ≥65 years (OR: 1.126, 95% CI: 1.091-1.172, P<0.001), smoking (OR: 1.395, 95% CI: 1.152-2.102, P=0.008), drinking (OR: 1.477, 95% CI: 1.268-2.669, P=0.002), TNM stage III (OR: 1.351, 95% CI: 1.185-1.925, P=0.010), TNM stage IV (OR: 2.005, 95% CI: 1.314-7.275, P<0.001) and TNBC subtype (OR: 2.173, 95% CI: 1.683-3.555, P=0.002) were independent risk factors for higher mGPS scores (Fig. 2).

mGPS is an independent predictor for OS in breast cancer. To evaluate the impact of clinical characteristics and the mGPS on OS, univariate and multivariate Cox proportional hazards regression analyses were conducted. In the univariate analysis (Table IV), several factors were associated with a higher risk of mortality, including age ≥65 years (HR: 3.376, 95% CI: 1.227-5.258, P<0.001), smoking (HR: 2.045, 95% CI: 1.183-4.904, P=0.001), drinking (HR: 1.762, 95% CI: 1.254-3.255, P=0.004), family history (HR: 1.827, 95% CI: 1.374-3.359, P=0.025), TNM stage III (HR: 2.659, 95% CI: 1.517-5.043, P=0.031), TNM stage IV (HR: 4.274, 95% CI: 2.654-7.268, P<0.001), TNBC subtype (HR: 3.053, 95% CI: 2.073-6.383, P<0.001) and mGPS scores of 1 (HR: 2.622, 95% CI: 1.674-5.538, P=0.001) and 2 (HR: 4.139, 95% CI: 2.822-9.163, P<0.001). In the multivariate Cox analysis, after adjusting for confounders such as age, BMI and PAM50 subtype, the mGPS score remained a significant independent predictor of OS. Patients with mGPS 1 had an HR of 1.322 (95% CI: 1.086-1.713, P=0.012) and those with mGPS 2 had an HR of 2.056 (95% CI: 1.751-4.322, P<0.001) when compared to patients with mGPS 0. Age ≥65 years (HR: 1.212, 95% CI: 1.132-1.455, P=0.001), smoking (HR: 1.173, 95% CI: 1.052-1.603, P=0.013), TNM stage III (HR: 1.114, 95% CI: 1.005-1.252, P=0.022), TNM stage IV (HR: 1.353, 95% CI: 1.157-1.776, P<0.001) and TNBC subtype (HR: 1.449, 95% CI: 1.257-1.748, P=0.038) were also independent predictors of worse OS (Fig. 3).

Nomogram based on mGPS accurately predicts survival. Based on the multivariate Cox regression model, a prognostic nomogram was developed incorporating age, smoking status, TNM stage, PAM50 subtype and mGPS score to predict

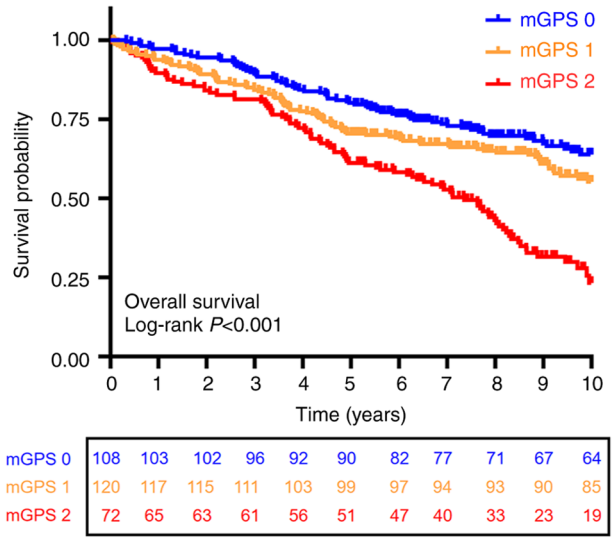

Figure 1. Kaplan-Meier survival curves for patients with breast cancer based on mGPS scores. The Kaplan-Meier survival curves display the OS of patients with breast cancer stratified by preoperative mGPS categories (mGPS 0, mGPS 1 and mGPS 2). The x-axis represents the follow-up time (in years), while the y-axis indicates the cumulative survival probability. Significant differences in survival were observed across the three groups, with higher mGPS scores associated with poorer survival outcomes (log-rank test, P<0.001). mGPS, modified Glasgow prognostic score; OS, overall survival.

5- and 10-year OS (Fig. 4). The nomogram demonstrated good predictive accuracy with a concordance index of 0.81 (95% CI: 0.75-0.88). Calibration curves showed strong agreement between the predicted and observed survival rates, indicating the model's robustness and applicability in clinical practice. For internal validation, bootstrapped resampling (1,000 repetitions) was performed, confirming the reliability of the nomogram.

Discussion

This study aimed to evaluate the prognostic value of the preoperative mGPS in patients with breast cancer undergoing surgery. The present findings firstly demonstrated that higher mGPS scores are significantly associated with poorer OS of patients with breast cancer, independent of other established clinical and pathological factors. This suggests that mGPS, a simple and cost-effective biomarker of systemic inflammation, may serve as an effective prognostic tool in clinical practice for patients with breast cancer.

Inflammation is increasingly recognized as a critical factor in cancer development and progression. The mGPS, based on serum CRP and Alb levels, reflects systemic inflammation and nutritional status. Elevated CRP levels indicate a pro-inflammatory state, while hypoalbuminemia reflects both malnutrition and inflammation (20,21). These factors may collectively impair the host's anti-tumor response and promote tumor progression. The current findings align with previous studies demonstrating that high mGPS scores are associated with poor prognosis in several cancers, including colorectal, lung and gastric cancers (22-27). The present study extends the prognostic utility of mGPS to breast cancer, showing that higher mGPS scores are associated with significantly lower 5- and 10-year survival rates.

Table III. Univariate analysis of risk factors associated with high mGPS scores.

Characteristic	OR	95% CI univariate analysis	P-value
Age (≥65 vs. <65 years)	2.836	1.783-4.545	<0.001
BMI	0.874	0.143-2.522	0.068
Smoking	3.214	1.948-5.267	<0.001
Drinking	2.180	1.355-3.486	0.002
Diabetes	1.357	0.268-2.641	0.312
Hypertension	1.851	1.129-3.525	0.761
Family history	2.536	1.263-3.248	0.137
TNM stage (I as reference)			
II	1.512	1.051-2.274	1.106
III	3.145	1.358-5.765	<0.001
IV	4.832	3.227-8.906	<0.001
PAM50 (ER+ or PR+ as reference)			
HER2+	0.928	0.403-1.275	2.004
TNBC	3.123	1.858-5.251	<0.001

OR, odds ratio; CI, confidence interval; TNM, tumor-node-metastasis; BMI, body mass index; PAM50, 50-gene intrinsic subtype classifier; ER, estrogen receptor; PR, progesterone receptor; TNBC, triple-negative breast cancer; HER2, human EGFR 2.

Traditional prognostic markers for breast cancer, such as tumor size, lymph node status, hormone receptor status, HER2 status and PAM50 molecular subtype, primarily focus on the tumor itself (28). However, these markers do not capture the host's systemic response to the tumor, which is an important determinant of patient outcomes (29). By integrating the mGPS into the prognostic assessment, clinicians may obtain a more comprehensive picture that includes both tumor characteristics and the host's inflammatory and nutritional status. The present multivariate analysis confirms that the mGPS is an independent predictor of OS, even after adjusting for other factors such as TNM stage, age and PAM50 subtype. This suggests that incorporating the mGPS into existing risk models may enhance their predictive accuracy and provide additional information for personalized treatment planning.

The biological mechanisms underlying the association between a high mGPS and poor prognosis in breast cancer likely involve several pathways. Chronic inflammation, as indicated by elevated CRP levels, is known to promote tumor growth, angiogenesis and metastasis (30). Inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α can create a tumor-promoting environment by enhancing cell proliferation and inhibiting apoptosis (31-33). In addition, systemic inflammation may lead to immunosuppression, reducing the effectiveness of the body's immune surveillance against tumor cells (34). Furthermore, hypoalbuminemia, a component of the mGPS, may indicate malnutrition or an

Table IV. Univariate Cox proportional hazards regression analysis of overall survival.

Characteristic	Total (n)	HR (95% CI) univariate analysis	P-value
Age	300	3.376 (1.227-5.258)	<0.001
BMI	300	0.539 (0.364-2.136)	0.132
Smoking	300	2.045 (1.183-4.904)	0.001
Drinking	300	1.762 (1.254-3.255)	0.004
Diabetes	300	3.318 (0.798-6.527)	0.003
Hypertension	300	2.434 (1.218-4.663)	1.672
Family history	300	1.827 (1.374-3.359)	0.025
TNM stage	300		
I	159	Reference	
II	94	1.268 (1.035-2.186)	3.846
III	35	2.659 (1.517-5.043)	0.031
IV	12	4.274 (2.654-7.268)	<0.001
PAM50	300		
ER+ or PR+	151	Reference	
HER2+	82	0.792 (0.512-2.195)	5.415
TNBC	67	3.053 (2.073-6.383)	<0.001
mGPS	300		
0	108	Reference	
1	120	2.622 (1.674-5.538)	0.001
2	72	4.139 (2.822-9.163)	<0.001

HR, hazard ratio; CI, confidence interval; BMI, body mass index; TNM, tumor-node-metastasis; PAM50, 50-gene intrinsic subtype classifier; ER, estrogen receptor; PR, progesterone receptor; HER2, human epidermal growth factor receptor 2; TNBC, triple-negative breast cancer; mGPS, modified Glasgow prognostic score.

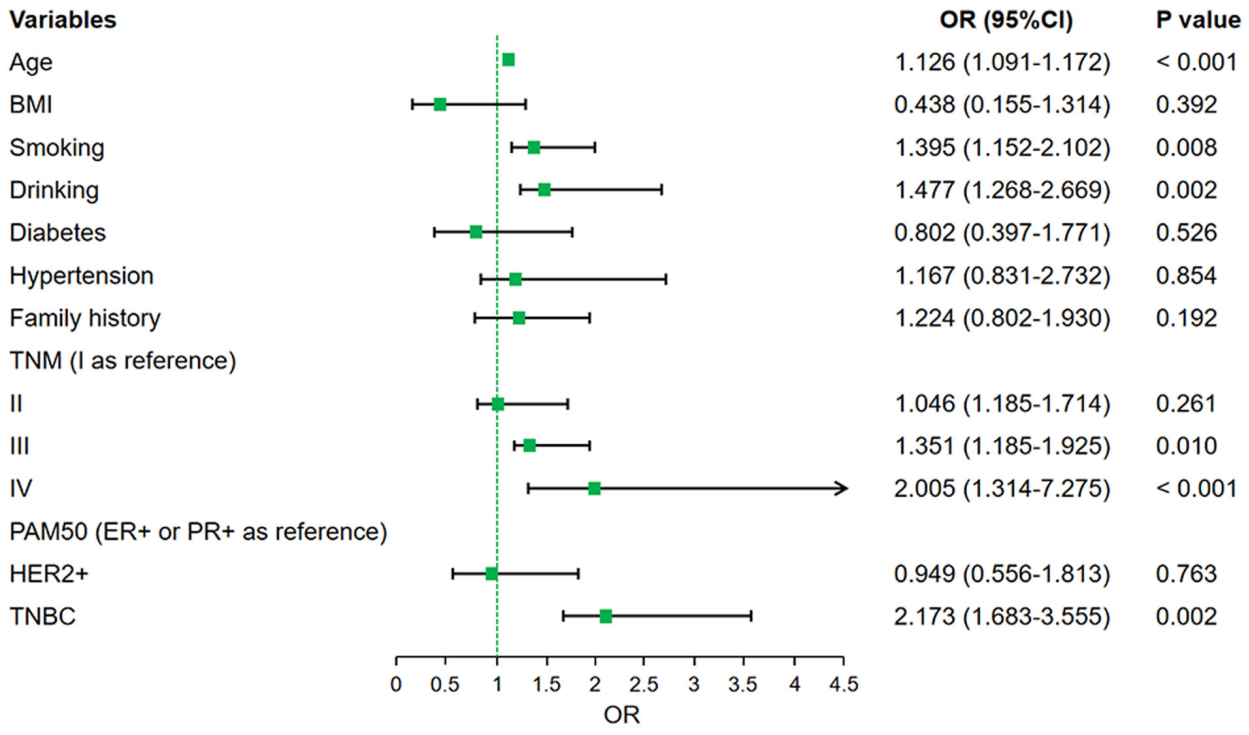

Figure 2. Risk factors associated with mGPS. Forest plot displaying the results of logistic regression analysis identifying clinical and pathological risk factors associated with a higher mGPS. The x-axis represents the ORs for each variable, while the y-axis lists the clinical and pathological factors, including age, smoking status, TNM stage and PAM50 subtype. Error bars indicate the 95% CIs for each OR. mGPS, modified Glasgow prognostic score; CI, confidence interval; OR, odds ratio; BMI, body mass index; ER, estrogen receptor; PR, progesterone receptor; TNBC, triple-negative breast cancer; PAM50, 50-gene intrinsic subtype classifier.

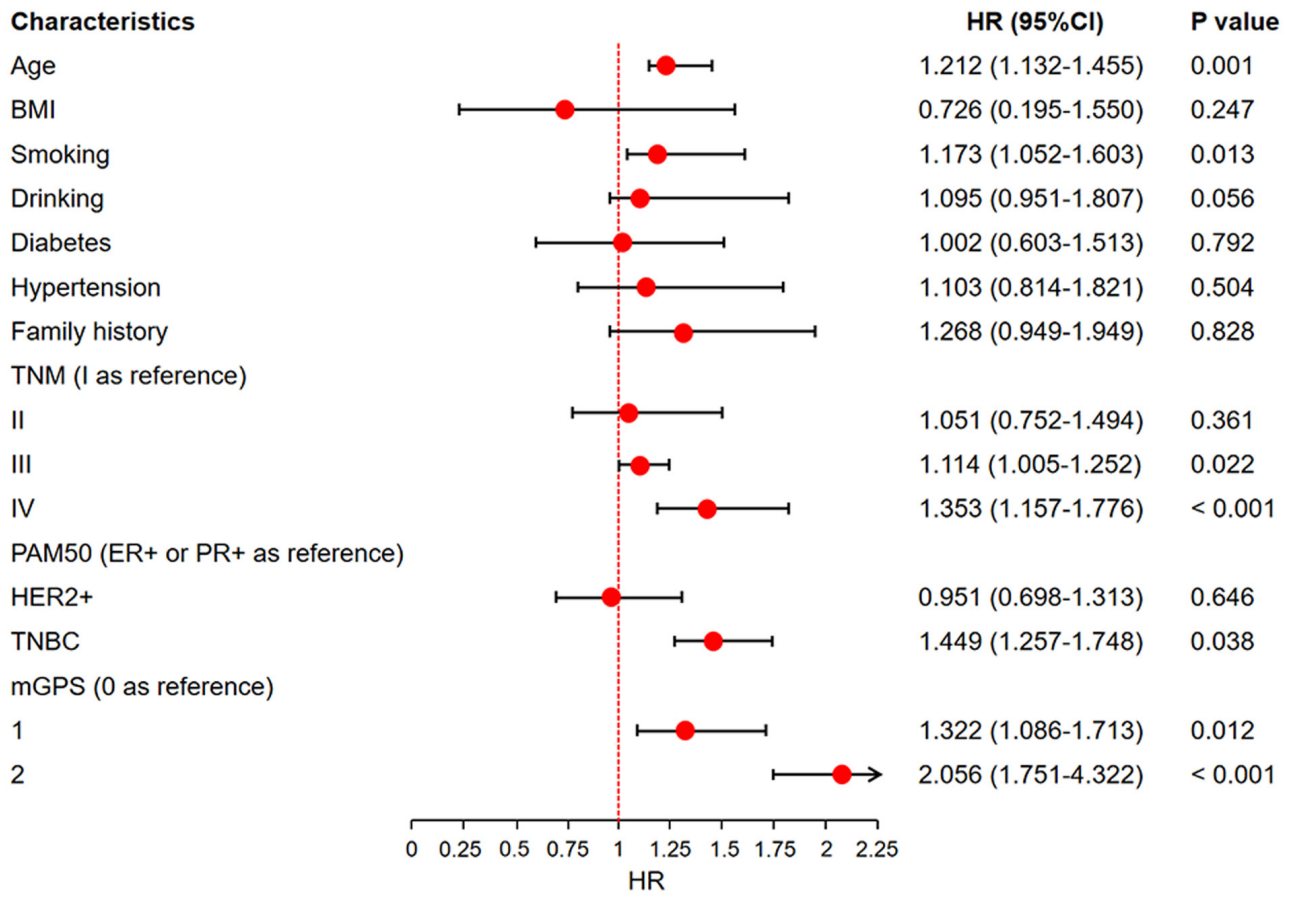

Figure 3. Multivariate Cox proportional hazards regression analysis of OS. The forest plot illustrates the HRs for OS based on multivariate Cox proportional hazards regression analysis. The x-axis represents the HRs, while the y-axis lists the clinical variables and mGPS. Variables included in the multivariate analysis were adjusted for potential confounders. Significant predictors of OS included mGPS, age, smoking and TNM stage (P<0.05). OS, overall survival; HR, hazard ratio; BMI, body mass index; ER, estrogen receptor; PR, progesterone receptor; mGPS, modified Glasgow prognostic score.

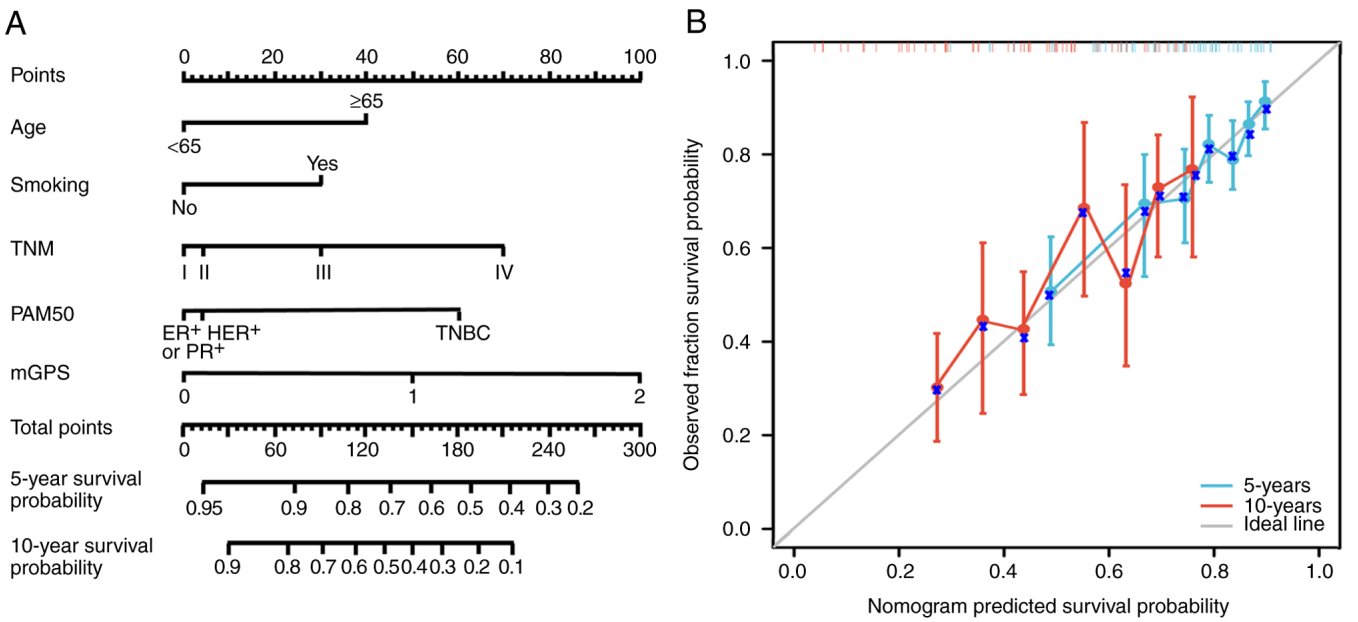

Figure 4. Nomogram for predicting 5- and 10-year OS. (A) A nomogram developed using multivariate Cox regression analysis incorporates age, smoking status, TNM stage, PAM50 subtype and mGPS to predict 5- and 10-year OS. Each variable is assigned a score, which is summed to estimate survival probabilities. (B) Calibration curves validate the predictive accuracy of the nomogram by comparing the predicted OS probabilities with observed outcomes. The dashed diagonal line represents perfect agreement and the solid lines indicate the calibration results for the model. The blue crosses represent individual patient data-points, showing the comparison between predicted and observed overall survival probabilities. OS, overall survival; mGPS, modified Glasgow prognostic score; ER, estrogen receptor; PR, progesterone receptor; TNBC, triple-negative breast cancer; HER2, human EGFR 2; TNM, tumor-node-metastasis; PAM50, 50-gene intrinsic subtype classifier.

advanced inflammatory state, both of which are associated with poorer outcomes in cancer patients. Alb has antioxidant properties and plays a role in maintaining oncotic pressure and drug binding; its reduction may contribute to poorer clinical conditions and reduced efficacy of therapies (35-37). The combination of elevated CRP and low Alb in the mGPS scoring system may therefore capture a more comprehensive picture of a patient's inflammatory and nutritional status, which is crucial in understanding breast cancer prognosis.

Although the present study demonstrates the independent prognostic value of the preoperative mGPS in assessing the prognosis of patients with breast cancer, it is important to acknowledge the limitations of this scoring system. First, mGPS only considers two factors-systemic inflammation and nutritional status- and does not account for other key factors that may affect the prognosis of patients with breast cancer, such as the tumor microenvironment, immune cell infiltration and genetic mutations or molecular characteristics. For instance, molecular subtypes of breast cancer (e.g., TNBC) and the HER2+ status have been shown to be closely related to survival outcomes (38), but these factors are not included in the mGPS. Therefore, the mGPS should be considered a supplementary tool for prognostic evaluation rather than the sole prognostic criterion. Secondly, as a blood biomarker-based tool, the mGPS does not reflect the local tumor characteristics or changes in other clinical factors. Over the follow-up period, patients with breast cancer may experience various events that impact survival, including recurrence, metastasis and treatment-related side effects, none of which are captured by the mGPS. Thus, the mGPS can only provide a snapshot of the patient's overall health status and cannot fully replace real-time monitoring of tumor dynamics. In addition, because the present study is a retrospective cohort analysis, the quality and completeness of the data collection may be influenced by the patients' medical records and follow-up data. Although efforts were made to control potential confounding factors through strict inclusion criteria and multivariate adjustments, it is impossible to rule out the possibility that certain important clinical information was not recorded or considered in the real clinical environment. The present study was conducted at a single institution, which may limit the generalizability of the current findings. Future prospective studies involving multiple centers and larger patient populations are needed to validate the present results and explore the potential role of mGPS in guiding treatment decisions. One of the limitations of the present study is the inability to monitor the impact of certain factors, such as the patient's age, the occurrence of other diseases during the 10-year follow-up period and the recurrence of breast cancer, on survival outcomes. However, considering that the preoperative mGPS was used in this study, this limitation may not apply to the preoperative prognosis, as the factors mentioned here typically occur later during the follow-up period, after the initial surgery. Therefore, these factors are more relevant to predicting postoperative survival outcomes, rather than affecting the preoperative prognosis assessed by the mGPS. These factors can significantly influence prognosis and may have confounded the relationship between mGPS scores and OS. Although the analysis controlled for known clinical variables, such as TNM stage and PAM50 subtype, the long-term nature of the follow-up and the lack of detailed data on these additional factors pose a limitation to the present findings. Future prospective studies should aim to comprehensively monitor these variables to better understand their effects on the survival of patients with breast cancer. Finally, there are inherent limitations to the mGPS itself. For instance, CRP and albumin levels are influenced by numerous non-cancer-related factors, such as infection, surgical trauma and other chronic diseases, which may lead to bias in the mGPS score. While patients with immunosuppressive therapy or inflammatory diseases were excluded, further validation of the stability and reliability of the mGPS in different clinical contexts is still needed. In conclusion, while the mGPS is a simple and cost-effective prognostic tool, its clinical application in breast cancer should be combined with other clinical and pathological features to provide a more comprehensive and accurate survival prediction. Therefore, it is recommended that in clinical practice, the mGPS should be used alongside other molecular biomarkers, immunological indicators and tumor microenvironment characteristics to further improve the accuracy of prognostic assessments and the precision of personalized treatment.

In conclusion, this study was the first to investigate the impact of the preoperative mGPS on the long-term prognosis of patients with breast cancer, with follow-up extending up to 10 years. The current findings show that the mGPS is an independent predictor of OS, with a higher mGPS associated with significantly poorer 5- and 10-year survival rates. Combining the mGPS with other clinical and pathological factors provides an effective risk stratification tool for guiding personalized treatment and follow-up strategies. Future studies should validate these results in larger cohorts and explore mGPS-targeted interventions to improve patient outcomes.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

JJF and BLM contributed to the conception and design of the study. YC, BXZ and XLW, MA and YYC collected and analyzed data. YC and BXZ wrote and revised the manuscript. BXZ and YYC confirm the authenticity of all the raw data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Affiliated Cancer Hospital of Xinjiang Medical University (Urumqi, China; approval no. K-2024056) in accordance with

the Declaration of Helsinki. All of the patients had signed a written informed consent form, which included consent to participate in the study, use of their medical data for research purposes and the publication of anonymized findings.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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