# 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.

## 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.

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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
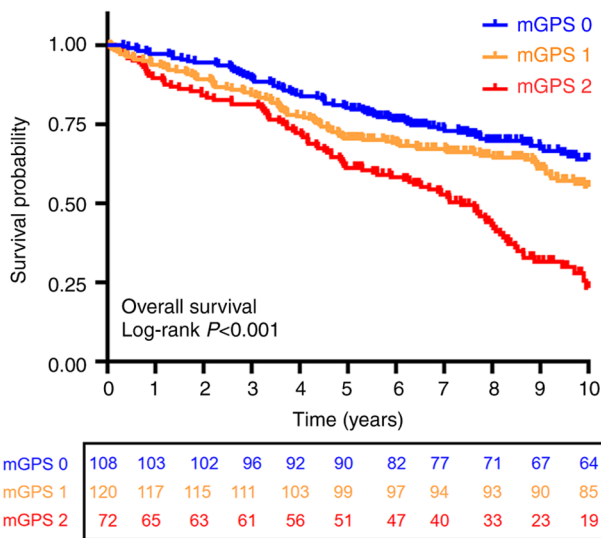
Figure 1. Kaplan-Meier survival curves for patients with breast cancer based on mGPS scores. The Kaplan-Meier survival curves display the OS of patients with breast cancer stratified by preoperative mGPS categories (mGPS 0, mGPS 1 and mGPS 2). The x-axis represents the follow-up time (in years), while 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.
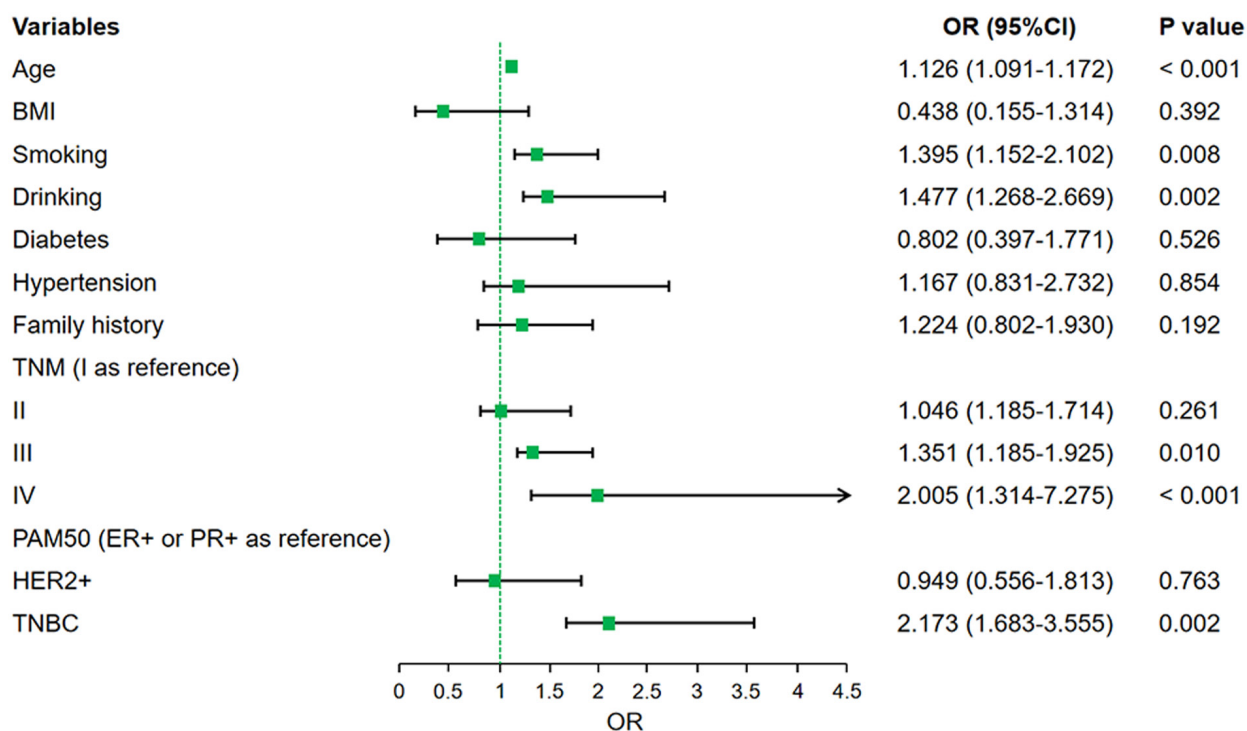


Figure 2. Risk factors associated with mGPS. Forest plot displaying the results of logistic regression analysis identifying clinical and pathological risk factors associated with a higher mGPS. The x-axis represents the ORs for each variable, while the y-axis lists the clinical and pathological factors, 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.
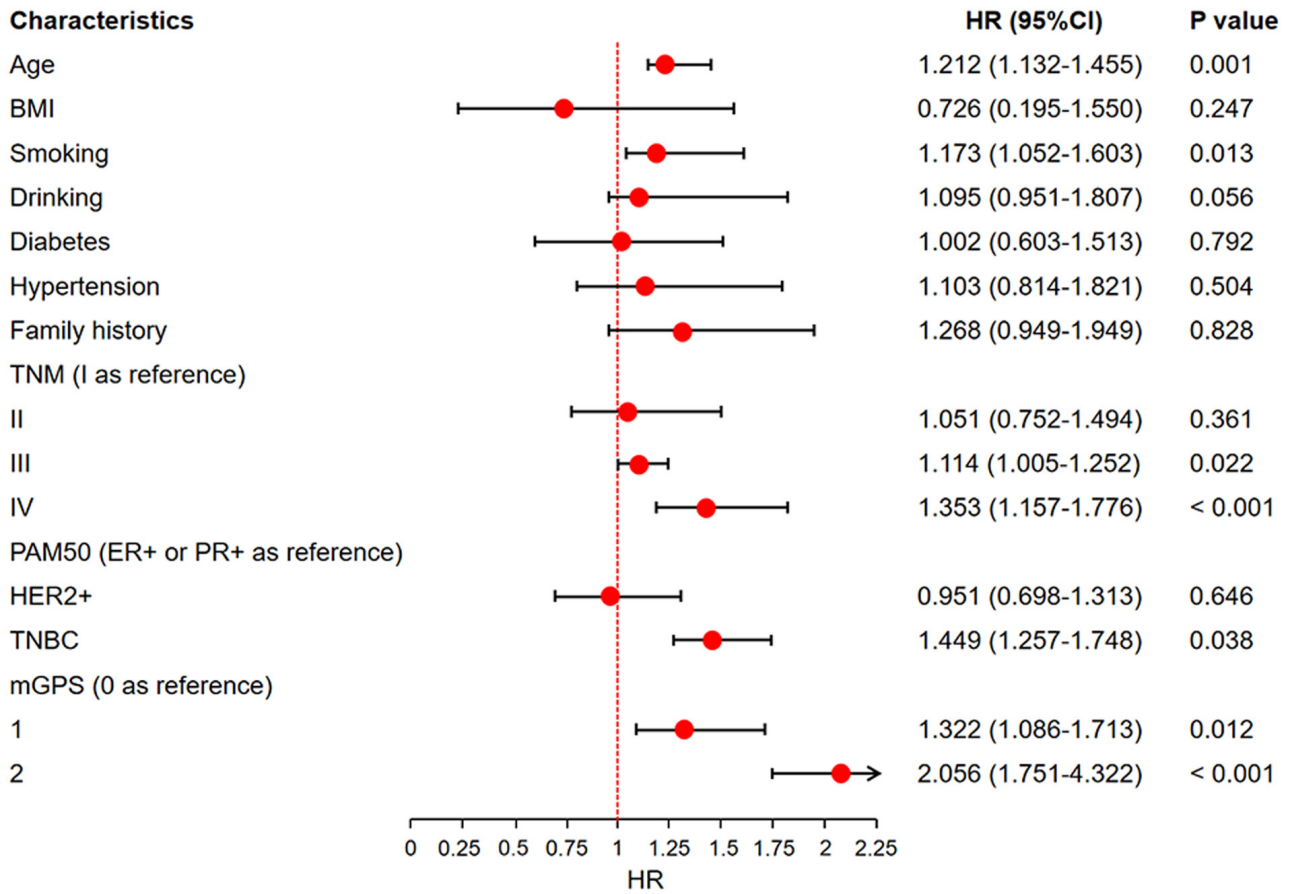
Figure 3. Multivariate Cox proportional hazards regression analysis of OS. The forest plot illustrates the HRs for OS based on multivariate Cox proportional hazards regression analysis. The x-axis represents the HRs, while the y-axis lists the clinical variables and mGPS. Variables included in the multivariate 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.
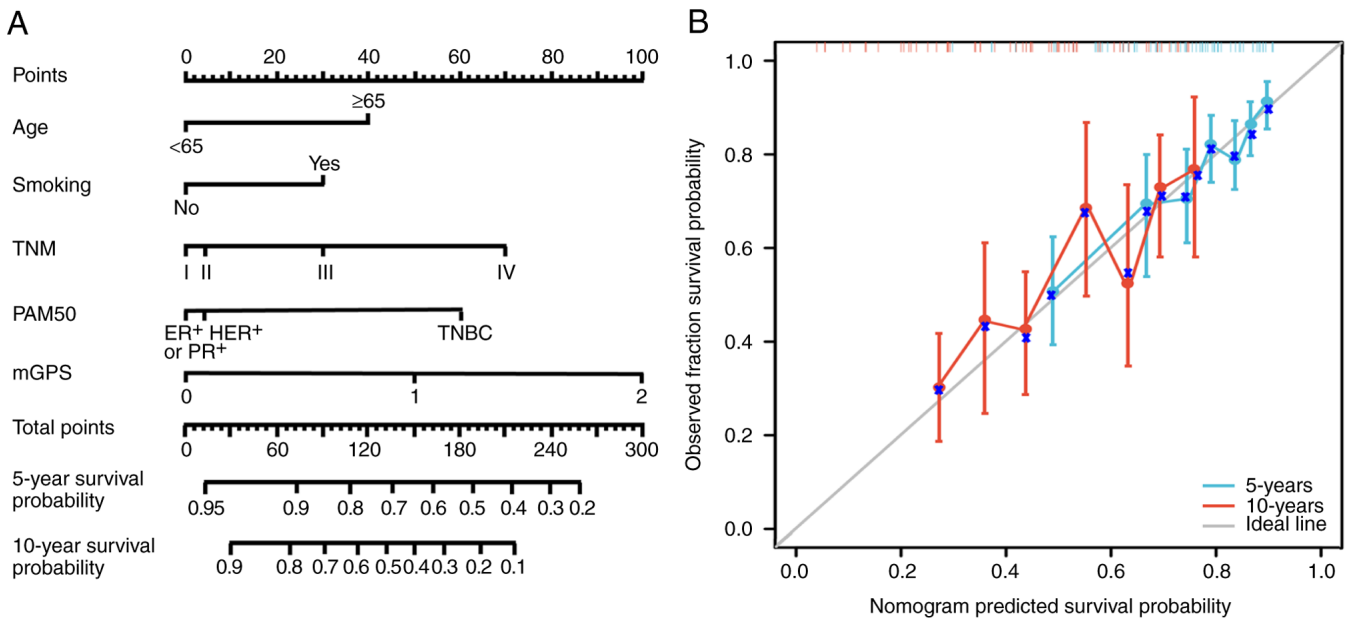


Figure 4. Nomogram for predicting 5- and 10-year OS. (A) A nomogram developed using multivariate Cox regression analysis incorporates age, smoking status, TNM stage, PAM50 subtype and mGPS to predict 5- and 10-year OS. Each variable is assigned a score, which is summed to estimate survival probabilities. (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.

## 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.

## References

1. Nguyen HM, Paulishak W, Oladejo M and Wood L: Dynamic tumor microenvironment, molecular heterogeneity, and distinct immunologic portrait of triple-negative breast cancer: An impact on classification and treatment approaches. Breast Cancer 30: 167-186, 2023.
2. Molinelli C, Jacobs F, Agostinetto E, Nader-Marta G, Ceppi M, Bruzzone M, Blondeaux E, Schettini F, Prat A, Viale G, et al: Prognostic value of HER2-low status in breast cancer: A systematic review and meta-analysis. ESMO Open 8: 101592, 2023.
3. Qi X, Qiao B, Song T, Huang D, Zhang H, Liu Y, Jin Q, Yang M and Liu D: Clinical utility of the pan-immune-inflammation value in breast cancer patients. Front Oncol 13: 1223786, 2023.
4. Zhang Y, Chen S, Chen H and Li W: A comprehensive analysis of Glasgow Prognostic Score (GPS)/the modified Glasgow Prognostic Score (mGPS) on immune checkpoint inhibitor efficacy among patients with advanced cancer. Cancer Med 12: 38-48, 2023.
5. Zhang F, Wu Z, Sun S, Fu Y, Chen Y and Liu J: POEMS syndrome in the 21st century: A bibliometric analysis. Heliyon 9: e20612, 2023.
6. Zhang H, Gao Y, Ying J, Yu H, Guo R, Xiong J and Jiang H: Bibliometric analysis of global research on breast reconstruction after mastectomy for breast cancer from 2011 to 2021. J Cosmet Dermatol 22: 2071-2082, 2023.
7. Nie D, Zhang L, Wang C, Guo Q and Mao X: A high Glasgow prognostic score (GPS) or modified Glasgow prognostic score (mGPS) predicts poor prognosis in gynecologic cancers: A systematic review and meta-analysis. Arch Gynecol Obstet 301: 1543-1551, 2020.
8. Abbass T, Dolan RD, MacLeod N, Horgan PG, Laird BJ and McMillan DC: Comparison of the prognostic value of MUST, ECOG-PS, mGPS and CT derived body composition analysis in patients with advanced lung cancer. Clin Nutr ESPEN 40: 349-356, 2020.
9. Wu Z, Chen Y, Yu G and Ma Y: Research trends and hotspots in surgical treatment of recurrent nasopharyngeal carcinoma: A bibliometric analysis from 2000 to 2023. Asian J Surg 47: 2939-2941, 2024.
10. Zhang H, Jia L, Guo R, Xiong J and Jiang H: A bibliometric and visualized study on global trends of breast augmentation complications, 2011-2021. Gland Surg 12: 354-365, 2023.
11. Boukovala M, Modest DP, Ricard I, Fischer von Weikersthal L, Decker T, Vehling-Kaiser U, Uhlig J, Schenk M, Freiberg-Richter J, Peuser B, et al: Evaluation of the inflammation-based modified Glasgow Prognostic Score (mGPS) as a prognostic and predictive biomarker in patients with metastatic colorectal cancer receiving first-line chemotherapy: A post hoc analysis of the randomized phase III XELAVIRI trial (AIO KRK0110). ESMO Open 9: 103374, 2024.
12. Goktas Aydin S, Kutlu Y, Muglu H, Aydin A, Acikgoz O, Hamdard J, Karci E, Bilici A, Olmez OF and Yildiz O: Predictive significance of inflammatory markers and mGPS in metastatic castration-resistant prostate cancer treated with abiraterone or enzalutamide. Cancer Chemother Pharmacol 93: 71-78, 2024.
13. Li J, Wu Z, Pan Y, Chen Y, Chu J, Cong Y and Fang Q: GNL3L exhibits pro-tumor activities via NF-κB pathway as a poor prognostic factor in acute myeloid leukemia. J Cancer 15: 4072-4080, 2024.
14. Zhang H, Tang S, Biskup E, Zhang Y, Yong L, Chen L and Cai F: Long-term survival after diverse therapeutic modalities in malignant phyllodes tumors of the breast. Technol Cancer Res Treat 21: 15330338221121086, 2022.
15. Liu XY, Zhang X, Zhang Q, Ruan GT, Liu T, Xie HL, Ge YZ, Song MM, Deng L and Shi HP: The value of CRP-albumin-lymphocyte index (CALLY index) as a prognostic biomarker in patients with non-small cell lung cancer. Support Care Cancer 31: 533, 2023.
16. Di Castelnuovo A, Bonaccio M, Costanzo S, De Curtis A, Magnacca S, Persichillo M, Panzera T, Bracone F, Pignatelli P, Carnevale R, et al: The association between hypoalbuminemia and risk of death due to cancer and vascular disease in individuals aged 65 years and older: Findings from the prospective Moli-sani cohort study. EClinicalMedicine 72: 102627, 2024.
17. Shapaer T, Chen Y, Pan Y, Wu Z, Tang T, Zhao Z and Zeng X: Elevated BEAN1 expression correlates with poor prognosis, immune evasion, and chemotherapy resistance in rectal adenocarcinoma. Discov Oncol 15: 446, 2024.
18. Zou Y, Hu X and Deng X: Distant lymph node metastases from breast cancer-Is it time to review TNM cancer staging? JAMA Netw Open 4: e212026, 2021.
19. Veerla S, Hohmann L, Nacer DF, Vallon-Christersson J and Staaf J: Perturbation and stability of PAM50 subtyping in population-based primary invasive breast cancer. NPJ Breast Cancer 9: 83, 2023.
20. Zhang H, Xia T, Xia Z, Zhou H, Li Z, Wang W, Zhai X and Jin B: KIF18A inactivates hepatic stellate cells and alleviates liver fibrosis through the TTC3/Akt/mTOR pathway. Cell Mol Life Sci 81: 96, 2024.
21. Zhao H, Yu L, Wang L, Yin X, Liu K, Liu W, Lin S and Wang L: Integrated analysis of single-cell and bulk RNA sequencing data reveals immune-related lncRNA-mRNA prognostic signature in triple-negative breast cancer. Genes Dis 11: 571-574, 2023.
22. Reyes-Ruiz A, Calvillo-Rodriguez KM, Martínez-Torres AC and Rodríguez-Padilla C: The bovine dialysable leukocyte extract IMMUNEPOTENT CRP induces immunogenic cell death in breast cancer cells leading to long-term antitumour memory. Br J Cancer 124: 1398-1410, 2021.
23. Shayimu P, Awula M, Wang CY, Jiapaer R, Pan YP, Wu ZM, Chen Y and Zhao ZL: Serum nutritional predictive biomarkers and risk assessment for anastomotic leakage after laparoscopic surgery in rectal cancer patients. World J Gastrointest Surg 16: 3142-3154, 2024.
24. Hua S, Wang W, Yao Z, Gu J, Zhang H, Zhu J, Xie Z and Jiang H: The fatty acid-related gene signature stratifies poor prognosis patients and characterizes TIME in cutaneous melanoma. J Cancer Res Clin Oncol 150: 40, 2024.
25. Park YR, Jee W, Park SM, Kim SW, Bae H, Jung JH, Kim H, Kim S, Chung JS and Jang HJ: Viscum album induces apoptosis by regulating STAT3 signaling pathway in breast cancer cells. Int J Mol Sci 24: 11988, 2023.
26. Hacker UT, Hasenclever D, Baber R, Linder N, Busse H, Obermannova R, Zdrazilova-Dubska L, Valik D and Lordick F: Modified Glasgow prognostic score (mGPS) is correlated with sarcopenia and dominates the prognostic role of baseline body composition parameters in advanced gastric and esophagogastric junction cancer patients undergoing first-line treatment from the phase III EXPAND trial. Ann Oncol 33: 685-692, 2022.
27. Wu Z, Chen Y, Jiang D, Pan Y, Tang T, Ma Y and Shapaer T: Mitochondrial-related drug resistance lncRNAs as prognostic biomarkers in laryngeal squamous cell carcinoma. Discov Oncol 15: 785, 2024.
28. Ma L, Gao P, Liu Z, Jiao D, Ling R, Xiao J, Zhao Y, Wang Y, Yang H, Liu Y, et al: Association of a complete breast cancer pathologic response with axillary lymph node metastasis via neoadjuvant chemotherapy: Results from the CSBrS-012 study. Chin Med J (Engl) 137: 1369-1371, 2024.
29. Dimitrakopoulos FI, Goussia A, Koliou GA, Dadouli K, Batistatou A, Kourea HP, Bobos M, Arapantoni-Dadioti P, Tzaida O, Koletsa T, et al: Ten-year clinical outcome, toxicity and compliance of dose-dense sequential adjuvant administration of cyclophosphamide & epirubicin followed by docetaxel in patients with early breast cancer: A hellenic cooperative oncology group observational study (HE 10/10) with concurrent investigation of significance of tumor infiltrating lymphocytes. Breast 73: 103668, 2024.

30. Proctor MJ, Talwar D, Balmar SM, O'Reilly DS, Foulis AK, Horgan PG, Morrison DS and McMillan DC: The relationship between the presence and site of cancer, an inflammation-based prognostic score and biochemical parameters. Initial results of the Glasgow Inflammation Outcome Study. Br J Cancer 103: 870-6, 2010.
31. Haq ATA, Yang PP, Jin C, Shih JH, Chen LM, Tseng HY, Chen YA, Weng YS, Wang LH, Snyder MP, *et al*: Immunotherapeutic IL-6R and targeting the MCT-1/IL-6/CXCL7/PD-L1 circuit prevent relapse and metastasis of triple-negative breast cancer. Theranostics 14: 2167-2189, 2024.
32. Farhana A, Alsrhani A, Alghsham RS, Derafa W, Khan YS and Rasheed Z: Gold nanoparticles downregulate IL-6 expression/production by upregulating microRNA-26a-5p and deactivating the RelA and NF-κBp50 transcription pathways in activated breast cancer cells. Int J Mol Sci 25: 1404, 2024.
33. Chen Y, Maitiniyazi G, Li Z, Li T, Liu Y, Zhang R, Cao X, Gu D and Xia S: TNF-α mediates the association between dietary inflammatory index and depressive symptoms in breast cancer. Nutrients 15: 84, 2022.
34. Ruan GT, Xie HL, Hu CL, Liu CA, Zhang HY, Zhang Q, Wang ZW, Zhang X, Ge YZ, Lin SQ, *et al*: Comprehensive prognostic effects of systemic inflammation and Insulin resistance in women with breast cancer with different BMI: A prospective multicenter cohort. Sci Rep 13: 4303, 2023.
35. Gao W, Li M and Zhang Y: Fibrinogen/albumin ratio (FAR) in patients with triple negative breast cancer and its relationship with epidermal growth factor receptor expression. Onco Targets Ther 14: 5403-5415, 2021.
36. Xiang M, Zhang H, Tian J, Yuan Y, Xu Z and Chen J: Low serum albumin levels and high neutrophil counts are predictive of a poorer prognosis in patients with metastatic breast cancer. Oncol Lett 24: 432, 2022.
37. Wang MD, Duan FF, Hua X, Cao L, Xia W and Chen JY: A novel albumin-related nutrition biomarker predicts breast cancer prognosis in neoadjuvant chemotherapy: A two-center cohort study. Nutrients 15: 4292, 2023.
38. Yin L, Duan JJ, Bian XW and Yu SC: Triple-negative breast cancer molecular subtyping and treatment progress. Breast Cancer Res 22: 61, 2020.