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Surgical Resection Enhances Survival in Patients With Liver Metastases From Gastric Cancer: A Population-Based, Case-Control Study

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ABSTRACT

Background and Aims: Gastric cancer with liver metastases (GCLM) is a challenging condition that significantly reduces long-term survival rates, but recent advancements in surgical techniques have shown promise. This study aims to comprehensively evaluate the impact of surgical resection on survival rates in GCLM patients.

Methods: We conducted a population-based analysis utilizing the SEER database for patients diagnosed with GCLM between 2010 and 2015. Overall survival (OS) was compared between patients who underwent cancer-directed surgery (CDS) and those who did not. The overlap weighting method based on lasso regression with penalty factors was employed to minimize selection bias. Survival outcomes were compared using Kaplan-Meier curves and Cox proportional hazards models, with subgroup analyses to further explore the effects of surgery among patients.

Results: A total of 3694 patients with GCLM were identified. Of those, 354 (9.58%) patients underwent CDS. After propensity score adjustment, The median OS was significantly higher in the surgical resection group (12 months, 95% confidence interval (CI) 11–16) compared to the nonresection group (6 months, 95% CI: 5–6). Cox regression analysis revealed a substantial improvement in OS for the surgical resection group, with a hazard ratio (HR) of 0.562 (95% CI: 0.482–0.656), including patients with adverse conditions.

Conclusions: The analysis demonstrated a clear association between surgical resection and enhanced OS in GCLM patients. Nevertheless, further research endeavors should be undertaken to identify specific prognostic factors that aid in the selection of optimal candidates for surgical resection.

Abbreviations: CDS, cancer-directed surgery; Cis, confidence intervals; GC, gastric cancer; GCLM, gastric cancer with liver metastases; HRs, hazard ratios; IPW, inverse propensity score weighting; OS, overall survival; OW, overlap weighting; OW_pLasso, overlap weighting that incorporates lasso regression with penalty factors; PS, propensity score; SEER, surveillance, epidemiology, and end results; SRCC, signet-ring cell carcinoma..

1 | Introduction

Gastric cancer (GC) ranks among the most prevalent malignancies worldwide and is the third leading cause of cancer-related deaths, with an estimated 26,500 new cases and approximately 11,130 deaths projected for 2023 [1]. More than one-third of patients exhibit signs of distant metastases at the time of initial diagnosis, primarily due to the inconspicuous symptoms of early-stage GC. Liver metastases are present in approximately 3.5%–14% of GC patients and are among the most common sites of metastasis [2–8]. The existence of gastric cancer with liver metastases (GCLM) is associated with more aggressive tumor behavior, leading to an extremely poor prognosis [9–11]. While systemic chemotherapy is currently regarded as the standard treatment for GCLM patients [12], the prognosis for those undergoing chemotherapy remains dismal, with a 5-year survival rate of less than 10% [13–15].

The value of surgical intervention in patients with GCLM remains a subject of ongoing debate. The National Comprehensive Cancer Network recommends surgical resection in a palliative setting for stage IV GCLM patients who experience tumor-related symptoms such as bleeding, perforation, or obstruction [12]. On the other hand, the guidelines put forth by the Japanese Gastric Cancer Association suggest that gastrectomy may be a viable option for patients with liver metastases who do not exhibit severe symptoms [16]. While the lack of randomized controlled trials investigating the direct impact of surgery on survival outcomes in GCLM patients is notable, a number of retrospective studies and meta-analyses have consistently reported significant survival benefits associated with surgical resection in stage IV cancers [7, 8, 17–33].

In this study, we propose the hypothesis that surgical intervention in patients with GCLM may enhance long-term survival outcomes compared to nonsurgical management. This hypothesis will be tested by conducting a comprehensive population-based study utilizing data from the surveillance, epidemiology, and end results (SEER) database spanning the years 2010 to 2015. To mitigate potential selection bias arising from measured patient characteristics, we employed the propensity score weighting method with overlap weights.

2 | Materials and Methods

2.1 | Data Source

The SEER data from 18 population-based cancer registries covering about 28% of the US population was used to identify patients with gastric cancer (www.seer.cancer.gov). This study was restricted to cases with liver metastases from January 2010 to December 2015, as the database did not provide related information until 2010.

2.2 | Study Population

We collected data using the SEER*Stat software (Version 8.4.0.). Gastric cancer was identified by the International Classification of Diseases for Oncology (ICD-O-3) codes C16.0-C16.9. Inclusion criteria were as follows [1]: Metastases in the liver [2]; Age ≥ 18 years [3]; Gastric cancer was the first diagnosed malignancy. SEER lacks information on metachronous metastasis. All of our analysis was based on synchronous liver metastasis. Patients with no evidence of a primary tumor, diagnosed with autopsy or death certificate, survival < 1 month, lacked race information, and tumors identified as diffuse carcinoma or linitis plastic were excluded. Additionally, we excluded patients who: were unknown if surgery was performed, surgery was contraindicated due to other conditions, and died before recommended surgery. The remaining patients were categorized into the CDS group (cancer-directed surgery performed) and the Non-CDS group (cancer-directed surgery not performed, resulting in 3694 patients (Figure 1). This study was conducted in accordance with ethical standards, and ethical approval was obtained from the relevant institutional review board. Informed consent was waived due to the use of deidentified data from the SEER database.

2.3 | Covariates and Endpoints

Tumor sites were categorized as: cardia (C16.0), body (C16.1-2, C16.5-6), lower (C16.3-4), overlapping lesion (C16.8), and not-specified (C16.9). Grade was categorized into the following groups; well/moderately differentiated (Grade I–II), poorly differentiated/undifferentiated (Grade III–IV), and unknown. Histological types were defined by the following ICD-O-3 codes: 8140 for adenocarcinoma, 8490 for signet ring cell carcinoma, and the remaining for others. Staging was classified by the 7th edition of the American Joint Committee on Cancer (AJCC) TNM staging system. Tumor size was categorized into four groups (< 2 cm, 2–5 cm, ≥ 5 cm, and unknown). Other patient characteristics including Age, Sex, Race, and Marital status was categorized into groups. The primary endpoint in this study was overall survival (OS), which was defined as the time interval from diagnosis to death due to any cause, or until the last follow-up time point.

2.4 | Statistical Analysis

Demographic characteristics and clinical variables were compared between the two groups using the chi-square test for categorical variables and the Student t test for continuous variables. To address potential biases arising from patient selection, we implemented the propensity score (PS) weighting method with overlap weights. This approach aimed to achieve balanced distributions of covariates across the two groups. Traditional inverse propensity score weighting (IPW) method may yield extreme weights when there is insufficient overlap in PS distributions between groups. To address this concern, we opted for the overlap weighting (OW) method, which estimates the treatment effect within the target population with the highest overlap in observed characteristics between the treatment groups [34, 35].

Specifically, we first estimated the propensity score using a multivariate lasso regression model with the CDS group as the dependent variable. All of the baseline variables were included in the PS model. Furthermore, we introduce a propensity score weighting method called "OW_pLasso", which uses overlap weighting to balance groups and employs lasso regression with penalty factors to identify key variables while minimizing

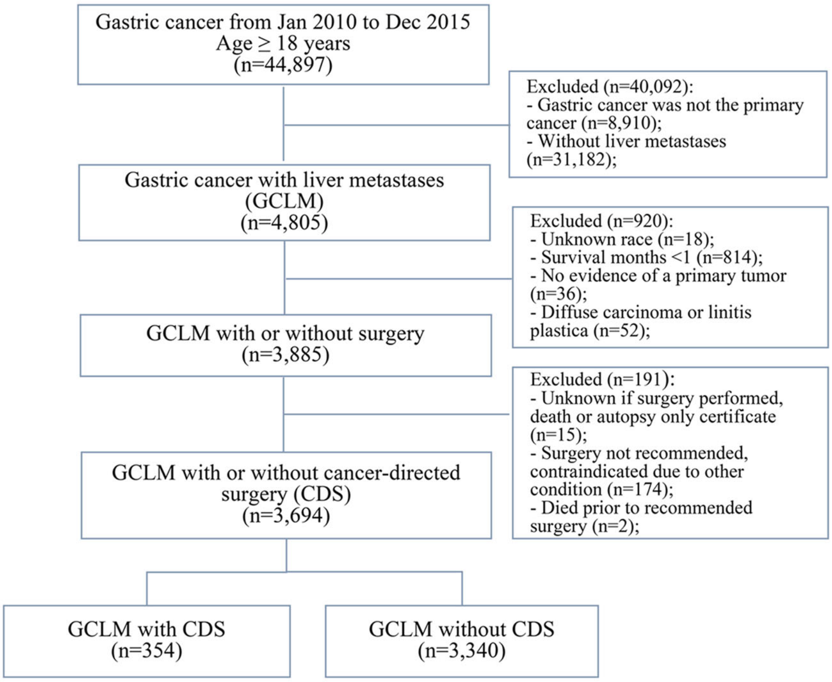

FIGURE 1 | Flow chart of patient selection.

model complexity. We conducted sensitivity analyses to compare various overlap weighting methods, including logistic regression, lasso regression, penalty lasso regression, random forest, gradient boosting machine, and XGBoost. Our results showed that OW approaches based on lasso and pLasso achieved the best overlap of propensity scores (Supporting Information S1: Figure S1A). Additionally, the standard mean differences for model variables obtained using the OW_pLasso method were significantly smaller than those derived from the standard lasso method (Supporting Information S1: Figure S1B). Therefore, we selected the OW_pLasso method for the subsequent weighting calculations.

Weights were assigned by assigning a weight of 1-PS to patients in the treatment arm and a weight of PS to those in the control arm. When applying the OW_pLasso, factors identified as significant confounders for survival ($p < 0.1$ in both univariate and multivariate Cox regressions) would not be penalized, meaning their coefficients would not shrink within the model; otherwise, they would be included in the penalty process. The derived weights were then applied to the analyses of overall survival. We employed the Kaplan-Meier method with the log-rank test. Cox regression analysis was conducted to estimate hazard ratios (HRs) and their corresponding 95% confidence intervals (CIs). These tests were performed both before and after applying the weights. Additionally, subgroup analyses were conducted for Cox regression, with stratification based on all available covariates (excluding subgroups with missing data).

All statistical analysis was conducted using R software version 4.1.2. Weighted chi-squared tests were performed using the 'weights' package. Logistic regression and machine learning-based regression models were fitted using the packages "glmnet," "rpart," "gbm," "xgboost," and "caret." Propensity scores and standard mean differences were calculated with the 'cobalt' package. Log-rank tests and Cox model fitting were conducted using the 'survival' package, while Kaplan-Meier plots were generated with the "survminer" package. A p-value less than 0.05 (two-sided) was considered statistically significant.

3 | Results

3.1 | Patient Characteristics

The study included a total of 3,694 eligible patients with GCLM who underwent propensity score estimation. Among these, 354 (9.58%) received resection (CDS group), while 3340 (90.4%) did not (Non-CDS group) (Figure 1). The primary propensity score (PS) model included all study variables that exhibited significance ($p < 0.2$) in chi-square tests and log-rank tests. Baseline characteristics of the two groups were compared before and after the application of propensity score weighting (Table 1). Before propensity score weighting, patients in the CDS group had larger tumor sizes, lower site tumors, a lower ratio of adenocarcinoma cancers, poorly differentiated tumors, advanced T and N stages, and were less likely to receive chemotherapy and radiation compared to the Non-CDS group. However, after OW_pLasso adjustment, no significant differences were observed in these characteristics between the two groups (Table 1). The OW_pLasso-adjusted standardized differences for baseline characteristics were all below 0.1 and close to zero (Supporting Information S1: Figure S1B).

3.2 | Overall Survival

Unweighted median OS was 12 months (95% CI = 11–16) in the CDS group and 6 months (95% CI = 5–6) in the Non-CDS group. After OW_pLasso adjustment, these values were 13 months

TABLE 1 | Comparison of patient characteristics between CDS and Non-CDS groups before and after propensity score weighting.

Variables	Unweighted, *n* (%)				OW_pLasso weighted, %		
	Overall (*N* = 3694)	CDS (*N* = 354)	Non-CDS (*N* = 3340)	*p* value	CDS	Non-CDS	*p* value
Age, years							
Median [IQR]	65.0 [18.0, 85.0]	65.0 [18.0, 85.0]	65.0 [21.0, 85.0]	0.311	64.0 [56.0, 74.0]	64.0 [56.0, 74.0]	0.945
Age Group				0.165			> 0.99
18–39	135 (3.7%)	19 (5.4%)	116 (3.5%)		4.2%	4.2%	
40–64	1678 (45.4%)	155 (43.8%)	1523 (45.6%)		45.9%	45.9%	
65–79	1386 (37.5%)	140 (39.5%)	1246 (37.3%)		38.7%	38.7%	
≥ 80	495 (13.4%)	40 (11.3%)	455 (13.6%)		11.1%	11.1%	
Sex				0.001			> 0.99
Male	2602 (70.4%)	222 (62.7%)	2380 (71.3%)		65.8%	65.8%	
Female	1092 (29.6%)	132 (37.3%)	960 (28.7%)		34.2%	34.2%	
Race				< 0.001			> 0.99
White	2631 (71.2%)	211 (59.6%)	2420 (72.5%)		64.5%	64.5%	
Black	595 (16.1%)	82 (23.2%)	513 (15.4%)		21.5%	21.5%	
Others	468 (12.7%)	61 (17.2%)	407 (12.2%)		13.9%	13.9%	
Marital Status				0.045			> 0.99
Married	2130 (57.7%)	222 (62.7%)	1908 (57.1%)		61.7%	61.7%	
Unmarried/Separated	1400 (37.9%)	113 (31.9%)	1287 (38.5%)		32.5%	32.5%	
Unknown	164 (4.4%)	19 (5.4%)	145 (4.3%)		5.8%	5.8%	
Tumor Size				< 0.001			> 0.99
< 2 cm	84 (2.3%)	19 (5.4%)	65 (1.9%)		4.9%	4.9%	
2–5 cm	612 (16.6%)	76 (21.5%)	536 (16.0%)		21.0%	21.0%	
≥ 5 cm	1000 (27.1%)	207 (58.5%)	793 (23.7%)		49.7%	49.7%	
Unknown	1998 (54.1%)	52 (14.7%)	1946 (58.3%)		24.5%	24.5%	
Primary site				< 0.001			> 0.99
Cardia	1539 (41.7%)	61 (17.2%)	1478 (44.3%)		25.2%	25.2%	
Body	832 (22.5%)	104 (29.4%)	728 (21.8%)		28.7%	29.0%	
Lower	507 (13.7%)	113 (31.9%)	394 (11.8%)		22.4%	22.4%	
Overlapping lesion	231 (6.3%)	26 (7.3%)	205 (6.1%)		7.3%	7.1%	
Not specified	585 (15.8%)	50 (14.1%)	535 (16.0%)		16.4%	16.4%	
Histologic type				< 0.001			> 0.99
Adenocarcinoma	2404 (65.1%)	143 (40.4%)	2261 (67.7%)		47.6%	47.6%	
Signet ring-cell carcinoma	226 (6.1%)	17 (4.8%)	209 (6.3%)		5.1%	5.1%	
Others	1064 (28.8%)	194 (54.8%)	870 (26.0%)		47.3%	47.3%	
Grade				< 0.001			> 0.99
I–II	1010 (27.3%)	120 (33.9%)	890 (26.6%)		31.1%	31.1%	
III–IV	1809 (49.0%)	182 (51.4%)	1627 (48.7%)		49.5%	49.5%	
Unknown	875 (23.7%)	52 (14.7%)	823 (24.6%)		19.4%	19.4%	
Chemotherapy				0.002			> 0.99
Yes	2434 (65.9%)	207 (58.5%)	2227 (66.7%)		65.6%	65.6%	
No/Unknown	1260 (34.1%)	147 (41.5%)	1113 (33.3%)		34.4%	34.4%	

(Continues)

TABLE 1 | (Continued)

Variables	Unweighted, *n* (%)				OW_pLasso weighted, %		
	Overall ($N = 3694$)	CDS ($N = 354$)	Non-CDS ($N = 3340$)	*p* value	CDS	Non-CDS	*p* value
Radiation				0.027			> 0.99
Yes	653 (17.7%)	47 (13.3%)	606 (18.1%)		17.2%	17.2%	
No/Unknown	3041 (82.3%)	307 (86.7%)	2734 (81.9%)		82.8%	82.8%	
T stage				< 0.001			> 0.99
T1	708 (19.2%)	29 (8.2%)	679 (20.3%)		12.5%	12.5%	
T2	131 (3.5%)	21 (5.9%)	110 (3.3%)		7.2%	7.2%	
T3	485 (13.1%)	128 (36.2%)	357 (10.7%)		30.6%	30.6%	
T4	665 (18.0%)	145 (41.0%)	520 (15.6%)		35.1%	35.1%	
Unknown	1705 (46.2%)	31 (8.8%)	1674 (50.1%)		14.7%	14.7%	
N stage				< 0.001			> 0.99
N0	1327 (35.9%)	125 (35.3%)	1202 (36.0%)		42.4%	42.4%	
N1	1400 (37.9%)	89 (25.1%)	1311 (39.3%)		32.6%	32.6%	
N2	183 (5.0%)	56 (15.8%)	127 (3.8%)		11.1%	11.1%	
N3	162 (4.4%)	76 (21.5%)	86 (2.6%)		10.1%	10.1%	
Unknown	622 (16.8%)	8 (2.3%)	614 (18.4%)		3.8%	3.8%	

Abbreviations: CDS, cancer-directed surgery; IQR, interquartile range; OW_pLasso, overlap weighting method based on lasso regression with penalty factors.

(95% CI = 11–17) and 7 months (95% CI = 6–7), respectively. In the univariate Cox proportional hazards regression analysis, both before and after OW_pLasso adjustment, CDS was significantly associated with a survival benefit (HR = 0.480 [95% CI = 0.424–0.545, $p < 0.001$] vs. HR = 0.562 [95% CI = 0.482–0.656, $p < 0.001$]) (Figure 2).

3.3 | Subgroup Analyses

Forest plots depicting HRs for OS across subgroups were generated (Figure 3). The analysis showed a consistent overall survival benefit from surgery across most subgroups, exception for younger individuals aged 18–39 years, those with signet ring-cell carcinoma cancers, and those with advanced N stages (N2, N3) (Figure 3). Detailed estimated HRs and median OS for each subgroup are presented in Table S1 and Table S2. Notably, CDS significantly prolonged survival for patients with large and high-grade tumors, advanced T stages, or limited lymph node metastases, with an OS extension of 10 months or more (Supporting Information S1: Table S2).

4 | Discussion

At present, the treatment options for stage IV gastric cancer include chemotherapy, radiotherapy, palliative surgery, immunotherapy, and targeted therapy. However, surgical resection for hepatic metastases from gastric cancer is rarely feasible due to multiple intrahepatic nodules and extra-hepatic metastases [36–38]. The absence of prospective randomized trials focusing on patients with GCLM has hindered the establishment of conclusive evidence regarding the efficacy of surgical intervention for these individuals. Clinical guidelines in the United States and Europe currently recommend surgery for stage IV patients who experience symptoms or complications [12, 39]. In contrast, the latest guidelines from the Chinese Society of Clinical Oncology advocate for sequential systemic chemotherapy followed by surgery in patients with a solitary liver metastasis [40], and Japanese guidelines suggest that asymptomatic patients with metastatic gastric cancer may be candidates for gastrectomy [16]. Therefore, there is an ongoing debate about whether surgical intervention improves survival rates in advanced GC cases.

This large population-based study provides robust evidence confirming the favorable outcomes of surgery on survival rates among patients diagnosed with GCLM. The main finding of this study is consistent with previous research suggesting the survival benefits of surgical resection in patients with metastatic GC [7, 8, 17–33, 41]. Supporting evidence includes a retrospective study demonstrating improved survival with sequential chemotherapy followed by surgery in certain patients with GCLM [26]. Additionally, Saito et al. suggested surgical resection for GC patients with metachronous hepatic metastases, even in the presence of various incurable factors [29]. A meta-analysis conducted by Sun et al. further investigated the suitability of palliative gastrectomy for patients with incurable advanced gastric cancer, revealing a significant improvement in survival for those with liver metastases (HR = 0.41, 95% CI = 0.30–0.55), which aligns with the findings of our study (unweighted HR = 0.480, 95% CI = 0.424–0.545) [41]. In a recent nationwide, multicenter clinical study involving 327 patients with initially resectable gastric cancer liver metastasis (IR-GCLM) in China [42], the results indicated that palliative surgery combined with systemic therapy serves as an

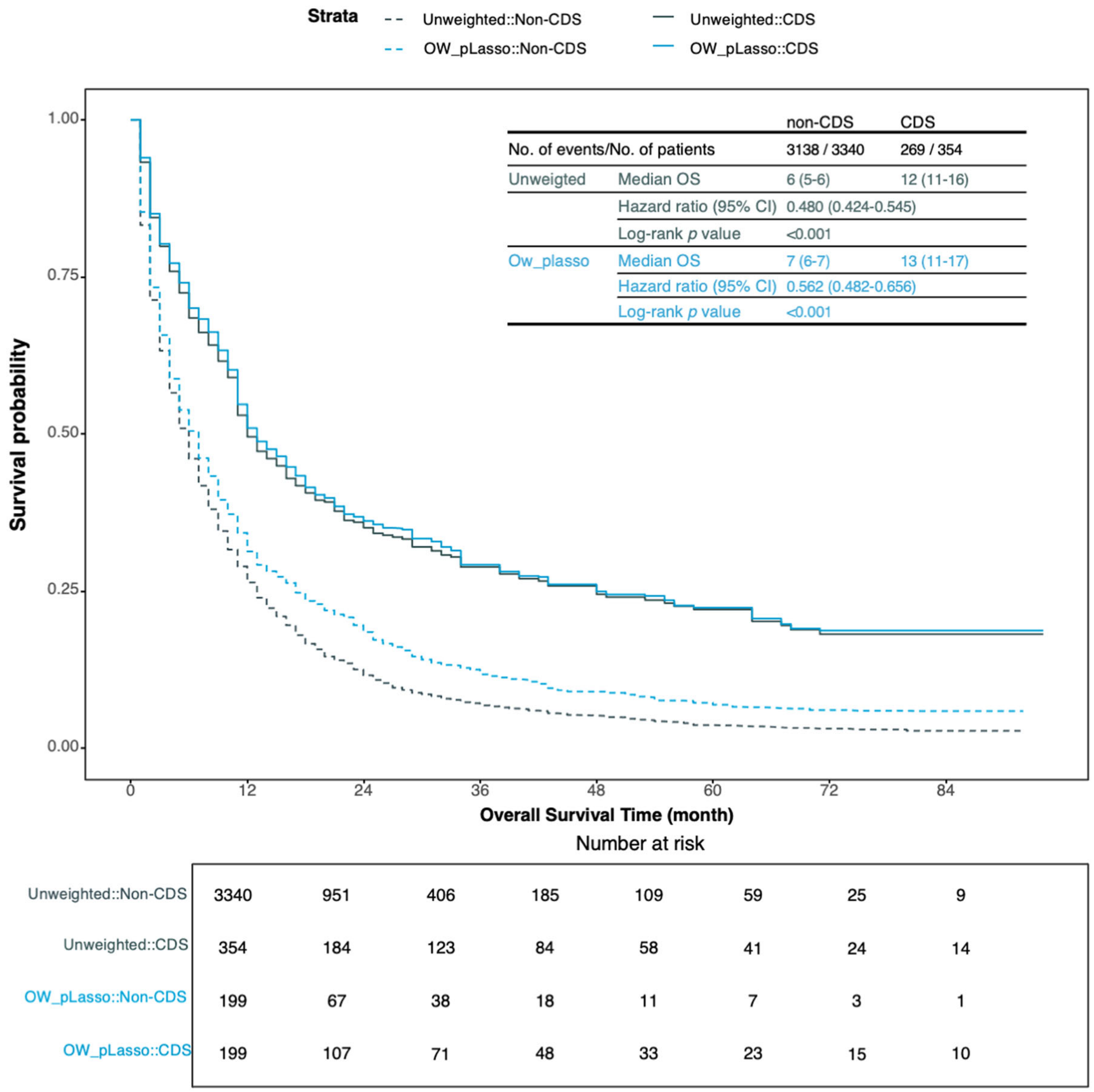

FIGURE 2 | Kaplan-Meier plots of overall survival between patients who did and did not receive CDS. CDS cancer-directed surgery, OW_pLasso overlap weighting method based on lasso regression with penalty factors, HR hazard ratio, Lower lower limits of confidence interval, Upper lower limits of confidence interval.

independent protective factor for the prognosis of IR-GCLM patients, compared to systemic therapy alone (HR = 0.30–0.70, $p < 0.05$). These findings further support the use of surgical resection before chemotherapy approach may lead to improved survival outcomes for GCLM patients. However, it is worth noting that the REGATTA study failed to demonstrate a survival benefit from palliative surgery followed by chemotherapy in metastatic gastric cancer patients, when compared to chemotherapy alone (median overall survival: 14.3 vs. 16.6 months) [43]. It is important to consider that the majority of patients in that trial had concomitant peritoneal metastases (approximately 75%), which could have potentially influenced the study results and limited the generalizability of the findings.

Another significant factor to consider regarding the results of the REGATTA trial is that the chemotherapy regimen employed was S-1 and cisplatin. The administration of oral medications can potentially lead to delays in chemotherapy and reduced treatment adherence. Consequently, evaluating the effects of the surgery itself becomes challenging. If the chemotherapy regimen had included intravenous agents (such as 5-fluorouracil, irinotecan, and docetaxel), which are standard treatment options in the United States, the treatment would likely be less affected by complications following gastrectomy. Additionally, the patients' conditions could also impact surgical outcomes; the majority (75%) of GCLM patients in the REGATTA trial had peritoneal metastasis, which is considered the worst prognostic type among patients with advanced gastric cancer.

Our study findings did not demonstrate any improvement in overall survival for patients with extensive lymph node metastasis and multiple lesions, which are known to be associated with a particularly poor prognosis [19, 25]. Previous studies by Shirabe et al. and Saiura et al. have suggested strict selection criteria for surgery, specifically excluding patients with lymphatic invasion

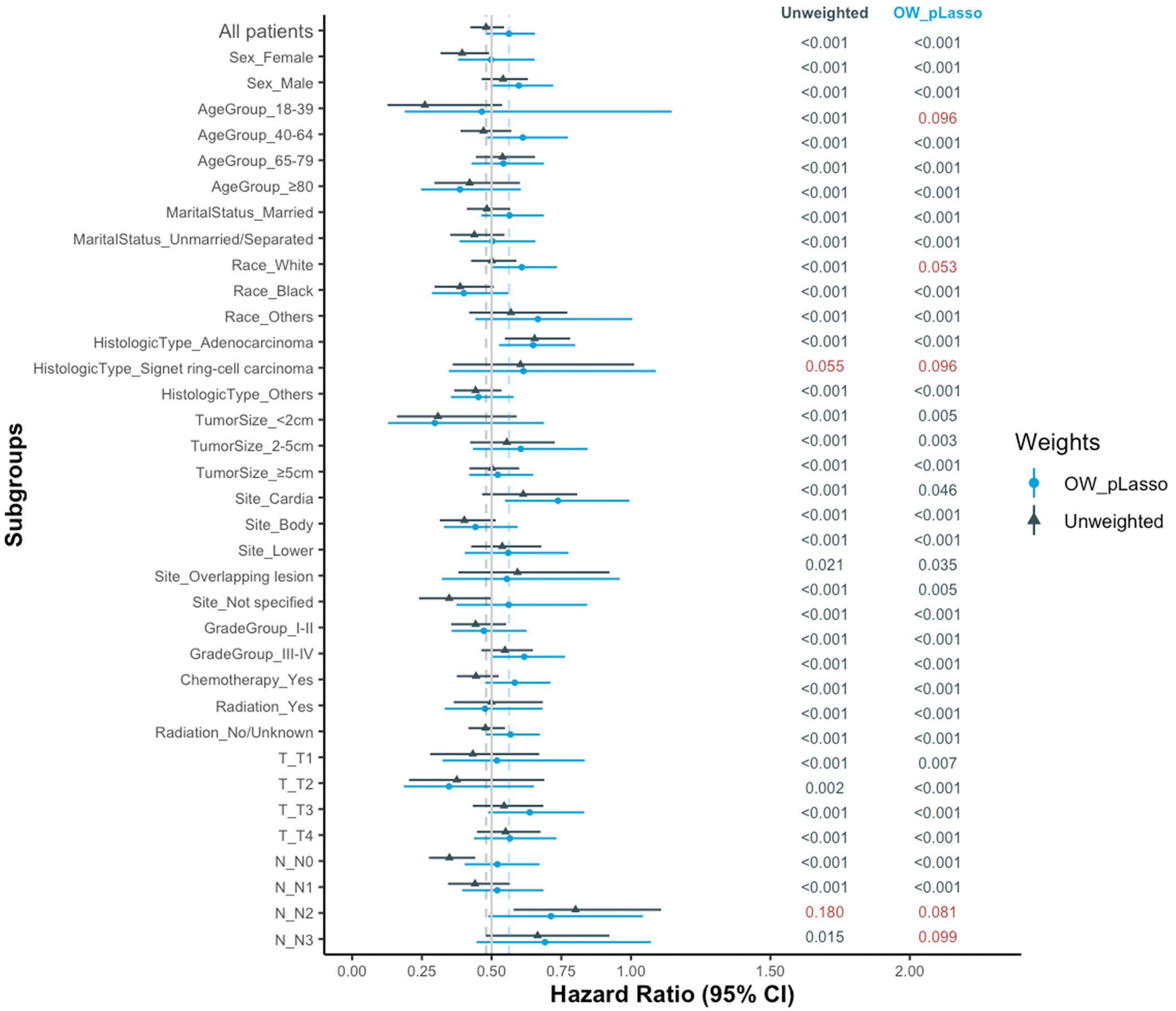

FIGURE 3 | Subgroup analyses of overall survival between patients who did and did not receive CDS. The left horizontal lines represent unadjusted (dark gray) and overlap weighting method based on lasso regression with penalty factors (OW_pLasso) weighted (blue) hazard ratios with 95% confidence intervals (CIs) for cancer-directed surgery (CDS) versus noncancer-directed surgery (non-CDS) across subgroups, while the right side displays the corresponding *p*-values, with those greater than 0.05 highlighted in red.

[7, 8]. However, the results of our study indicated a positive effect of surgery on survival in patients with fewer than 3 lymph nodes involved. This finding is consistent with a clinical phase 2 trial that adopted gastrectomy with D2 lymphadenectomy, showing a significant survival benefit from surgical resection in patients with limited metastatic gastric or gastroesophageal junction cancer (median overall survival: 31.3 vs. 15.9 months) [17]. The existing evidence suggests that surgical resection, including extended lymph node dissection, should be considered as a treatment option for gastric cancer patients with multiple lymph node metastases. Interestingly, in our results, the survival benefits did not persist in patients of younger age after adjustment using the OW_pLasso method. However, this may be attributed to the limited sample size of patients treated with surgery in this specific subgroup. Nonetheless, we observed a trend toward longer median overall survival time in these patients compared to those who did not receive surgical treatment (not reached vs. 7 months) (Supporting Information S1: Table S2). It is important to note that previous studies have identified younger age as a prognostic factor associated with improved survival outcomes [21, 44, 45]. We also found no survival benefits from surgery in patients with the signet-ring cell carcinoma (SRCC) type, which may be due to the distinct biological behavior of SRCC compared to other cell types. In advanced gastric cancer, SRCC is associated with higher aggressiveness, and several studies have shown that the 5-year survival rate for these patients was significantly lower than that of non-SRCC patients [46–48]. Additionally, the number of SRCC patients undergoing surgery was very low, with only 17 cases reported (Supporting Information S1: Table S1). Even if there were any survival improvement associated with surgery, the low sample size would likely limit the statistical power to detect such an effect.

Several limitations need to be acknowledged in this study. Firstly, the SEER database lacks information on certain factors that have previously been shown to be associated with the prognosis of gastric cancer, including peritoneal metastases, comorbidities, specific chemotherapeutic regimens and cycles, as well as the patients' performance status and clinical response. These factors may have a significant impact on treatment choices and prognosis in patients with GCLM. Second, due to the nature of observational studies, we cannot establish a causal link between surgery and survival outcomes in patients with GCLM. By using overlap weighting as a causal inference method, we aimed to emulate a target trial using observational data [49]. However, it is important to note that even with overlap weighting, unmeasured confounding variables can still introduce bias. If important confounders are not included in the model, the results may not accurately reflect the true treatment effect. For example, comorbidities have a significant impact on both patient prognosis and the effectiveness of surgery, but the SEER database does not collect this information, which prevents our results from reflecting the influence of this factor. Third, the SEER database does not provide information on metachronous liver metastases, limiting our ability to evaluate the effect of surgery in such cases. Nonetheless, previous research has suggested a potential prognostic benefit of hepatectomy in patients with metachronous liver metastases [18, 24, 30]. While our findings provide preliminary evidence of survival advantages associated with surgery, further studies are warranted to determine which patients with gastric cancer and liver metastases may benefit the most from surgical resection, given the missing key data points in the SEER database. Despite these limitations, this study is notable for its use of a registry-based database, allowing for a large-scale evaluation of the effectiveness of surgery in improving prognosis for patients with GCLM. The SEER registry provides a reflection of real-world outcomes for patients with metastatic gastric cancer, enhancing the generalizability of our findings. Additionally, previous studies have lacked an evaluation of the long-term survival benefits of surgery in patients with GCLM, whereas our study had a maximum follow-up time of 93 months, enabling a demonstration of the long-term survival benefits of surgery in a substantial number of patients.

Future research should focus on how our findings and the OW_pLasso model can be integrated into clinical decision-making frameworks, especially in regions with high gastric cancer burdens. By identifying specific prognostic factors—such as histopathological classifications, N staging, and the extent of liver metastasis—we can determine which patients are most likely to benefit from surgical resection and develop tailored treatment protocols that optimize patient outcomes. For instance, incorporating real-time data analytics and machine learning techniques could enhance the predictive accuracy of patient selection for surgery. Additionally, multicenter studies could be conducted to validate our findings across different regions, ensuring that the model are applicable in various healthcare settings.

5 | Conclusions

In this population-based study, we have demonstrated the significant survival improvements associated with surgical resection in patients with gastric cancer and liver metastases, regardless of the presence of severe conditions such as high-grade tumors, advanced T stages, and limited lymph node metastases. These findings provide valuable validation of the efficacy of surgical resection in this patient population. However, to further consolidate these results and address any remaining uncertainties, large-scale prospective studies are warranted. Such studies would provide a more robust evaluation of the role of surgical resection as a treatment modality for patients with gastric cancer and liver metastases.

Author Contributions

Wuhui Sun: conceptualization, data curation, formal analysis, investigation, methodology, software, visualization, writing–original draft. **Xiawei Li:** project administration, resources, supervision, writing–review and editing.

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All authors have read and approved the final version of the manuscript. Xiawei Li had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data presented in this study are openly available in the SEER Registries database (https://seer.cancer.gov/registries/). The datasets analyzed during the current study are available from the corresponding authors upon reasonable request.

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