Clin. Lab. 2025;71:XXX-XXX

ORIGINAL ARTICLE

CEA, CA19-9, and CA72-4 in Gastric Cancer Diagnosis and Progression: a Chinese Retrospective Case-Control Study

Lingyan Deng, Tongxin Yin, Huijun Li, Xu Wang, Jiaoyuan Li, Ke Liu, Tingting Long, Yi Wang, Liming Cheng

Department of Laboratory Medicine, Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

SUMMARY

Background: **The usefulness of serum carcinoembryonic antigen (CEA), carbohydrate antigen (CA) 19-9, and CA72-4 for diagnosis, predicting progression, and monitoring recurrence of gastric cancer (GC) remains unclear.**
Methods: **We conducted a retrospective investigation in this study. A total of 564 GC cases were enrolled, and 529 cases with benign gastric disease were recruited as controls. The clinical data and results of biomarker detections were collected.**
Results: **The median concentrations (IQR) of CEA, CA19-9, and CA72-4 in GC patients were 2.38 ng/mL (1.47 - 4.47), 10.52 U/mL (6.17 - 20.20), and 2.42 U/mL (1.26 - 6.58), respectively, which were significantly different from those in controls (all $p < 0.001$). However, the areas under the ROC curve (AUCs) were 0.633, 0.565, and 0.621, respectively. When combining the three biomarkers, the optimal sensitivity, specificity, and AUC were 39.15%, 86.93%, and 0.652, respectively. The concentrations of biomarkers increased incrementally with the pathological stages (all $p < 0.001$). However, the PPVs in comparison with early/advanced GC, no/with lymph node metastasis, and distant metastasis were modest. No significant difference in preoperative levels was observed in patients with and without recurrence. Significant difference was shown in both recurrence and no recurrence group when comparing the baseline and endpoint levels (all $p < 0.05$).**
Conclusions: **CEA, CA19-9, and CA72-4 were not applicable biomarkers for diagnosis, and the combination did not achieve better diagnosis efficiency. The levels of biomarkers cannot predict advanced GC, lymph node metastasis, and distant metastasis well. The measurements of biomarkers may not effectively identify recurrence after curative radical gastrectomy.**
(Clin. Lab. 2025;71:xx-xx. DOI: 10.7754/Clin.Lab.2024.240931)

Correspondence:
Dr. Liming Cheng, Professor
Department of Laboratory Medicine
Tongji Hospital
Tongji Medical College
Huazhong University of Science and Technology
Jiefang Ave. 1095
Wuhan, Hubei
P. R. China
Phone/Fax: + 86 2783665471
Email: chengliming2015@163.com

Manuscript accepted November 10, 2024

KEYWORDS

gastric cancer, carcinoembryonic antigen, carbohydrate antigen 19 - 9, carbohydrate antigen 72 - 4, diagnostic performance

INTRODUCTION

Gastric cancer (GC) is the fifth most commonly diagnosed malignancy and the fourth leading cause of cancer deaths worldwide [1]. In China, concerns about GC have received attention. It is estimated that there are 679,000 newly diagnosed GC cases and 498,000 cancer-related deaths occurring in 2015 [2]. Screening for early GC is difficult, particularly for asymptomatic indi-

viduals. Although the development of treatment offers new hope for advanced GC patients, the prognosis is still poor, with high recurrence. A previous study shows that the five-year survival rate of gastric cancer is only 36.7%, while the survival rate of early gastric cancer can reach up to 90.3% [3]. Therefore, early detection of GC is crucial to reduce the mortality and recurrence associated with the disease. Besides, the diagnosis and treatment are highly dependent on the staging of cancer, making accurate staging crucial throughout the course of GC.

Although endoscopic biopsy is the criterion standard for diagnosing GC, tumor markers have also been used for cancer diagnosis, guidance of treatment, monitoring of recurrence, and judgement of prognosis due to relatively low cost and less discomfort to the patients [4]. At present, GC still lacks tumor markers with high sensitivity and specificity. Carbohydrate antigen (CA) 72-4 is the most widely-used biomarker for GC and has a relatively high sensitivity and specificity for diagnosing GC compared with other indicators [5]. Except for CA72-4, other biomarkers, including carcinoembryonic antigen (CEA) and CA19-9, have also been reported to play an important role in monitoring GC recurrence and distant metastasis as well as evaluating the efficacy and prognosis of chemotherapy [6-9]. However, whether they can serve as applicable biomarkers for GC is still controversial.

In this study, we intended to investigate the clinical performance of serum CEA, CA19-9, and CA72-4 for distinguishing between malignant and benign gastric disease and to explore their use in monitoring the progression of GC.

MATERIALS AND METHODS

Study population

We conducted a retrospective study with 564 GC patients and 529 controls with benign gastric disease on the Chinese population. The participants were consecutively recruited between July 2019 and September 2020 at Tongji Hospital of Huazhong University of Science and Technology (HUST), Wuhan, China. Inclusion criteria were as follows: 1) a pathological diagnosis of GC or gross evidence of metastasis seen during surgery; 2) tests of CEA, CA19-9, CA72-4 were taken before any treatment including surgery, chemotherapy, and local/systemic radiotherapy. Exclusion criteria included: 1) GC not the primary focus but caused by metastasis of cancer in other tissues and organs of the body; 2) the presence of a second type of cancer in the body before admission. Controls with benign gastric disease were randomly selected from patients who were hospitalized during the same period. GC was excluded through endoscopic biopsy. All the subjects were unrelated Han Chinese.

Demographic, pathological, and laboratory data

Demographic data, smoking status, discharge diagnosis, pathological examination results, intraoperative findings, and GC biomarker test results (including CEA, CA19-9, and CA72-4) were collected. According to the results of pathological examination, TNM staging was performed on patients in GC group according to the 8th edition of AJCC/UICC TNM staging.

Serum CEA was measured by Abbott Architect I2000SR. Serum CA19-9 and CA72-4 levels were measured by Roche Cobas E602. The detection range of CEA was 0.5 - 1,500 U/mL, CA19-9 was 0.600 - 1,000 U/mL, and CA72-4 was 0.200 - 300 U/mL. Samples outside the detection range were diluted and retested. The coefficient of variation in our laboratory was 3.54% for CEA, 2.79% for CA19-9, and 3.28% for CA72-4. The normal ranges of CEA, CA19-9, and CA72-4, provided by the manufacturer, are: 0 - 5 ng/mL, 0 - 34 U/mL, and 0 - 6.9 U/mL, respectively.

Statistical analysis

Statistical analysis was performed using SPSS22.0, and data was displayed using GraphPad Prism 8.0 software. Continuous, normally distributed variables were presented as mean and 95% confidential interval (CI). Non-normal variables were expressed as median and interquartile range (IQR). Categorical variables were expressed as cases (%). Mann-Whitney U test was used to analyze differences between two independent non-normal distribution samples, and Wilcoxon signed rank test was used for paired non-normal distribution samples. The classified variables were compared by Pearson's chi-squared (χ^2) test. The significance of correlations between more than two variables was analyzed by Spearman rank test. Multiple comparisons were taken by Kruskal-Wallis test. Logistic regression was used to establish a combined detection parameter model based on the correlation between the levels of different biomarkers and the occurrence of GC. By plotting receiver operating characteristic (ROC) curve and calculating the area under the curve (AUC), the diagnosis and combined diagnostic value of different tumor markers for GC could be predicted. The cutoff value determined by Youden index was used to predict the optimal specificity and sensitivity of different biomarkers for the diagnosis of GC. The positive predictive values (PPVs) and negative predictive values (NPVs) were also displayed. In all cases, significance was defined as a p-value less than 0.05.

Ethical considerations

Our study has been approved by the ethical committee of Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology.

Table 1. Basic information and pathological features of benign and malignant gastric diseases.

Characteristics	Controls (n = 529) *	Cases (n = 564) *
Age (median, IQR)	54 (46 - 62)	58 (51 - 66)
Gender		
Male	257 (48.6)	382 (67.7)
Female	272 (51.4)	182 (32.3)
Smoking status		
Never	431 (81.5)	444 (78.7)
Former	29 (5.5)	49 (8.7)
Current	69 (13.0)	71 (12.6)
Degree of differentiation		
Poor differentiation		279 (49.5)
Moderate/high differentiation		200 (35.5)
Unknown		85 (15.0)
Histological type of cancer		
Adenocarcinoma		534 (94.7)
Squamous		2 (0.4)
Adenosquamous		1 (0.2)
Unknown		27 (4.8)
Tumor stage △		
Stage I		133 (23.6)
Stage II		123 (21.8)
Stage III		157 (27.8)
Stage IV		103 (18.3)
Unknown		48 (8.5)
Types of benign gastric disease		
Gastric ulcer	66 (12.5)	
Gastric polyps	226 (42.7)	
Chronic non-atrophic gastritis	106 (20.0)	
Gastric atrophy	52 (9.8)	
Intestinal metaplasia	79 (14.9)	

* - Unless otherwise noted, data are presented as cases (%).
△ - According to the 8th edition AJCC/UICC TNM staging system for gastric cancer (GC).

RESULTS

Demographic and clinical characteristics of the subjects

The clinical, pathological, and biochemical characteristics of 564 GC cases and 529 controls with benign gastric disease are summarized in Table 1. The median (IQR) ages at recruitment were 58 (51 - 66) and 54 (46 - 62) years in cases and controls, respectively. Further, 382 (67.7%) were male in cases and 257 (48.6%) in controls. Most GC cases were adenocarcinoma patients, and stage I and stage II patients occupied a proportion of 45.4%. Gastric polyps were reported in 226 (42.7%) controls, followed by non-atrophic gastritis in 106 (20.0%) cases, gastric ulcer in 66 (12.5%) cases, intestinal metaplasia in 79 (14.9%) cases, and gastric atrophy in 52 (9.8%) cases. There was no significant difference between the cases and controls in terms of smoking status ($p = 0.120$).

The distribution of CEA, CA19-9, and CA72-4 in the study subjects

The distribution of the three biomarkers are shown in Figure 1. A significant difference was observed between patients with benign and malignant gastric disease (all $p < 0.001$). In detail, the median concentrations (IQR) of CEA, CA19-9, and CA72-4 in controls were 1.79 ng/mL (1.24 - 2.59), 8.72 U/mL (5.91 - 15.17), and 1.58

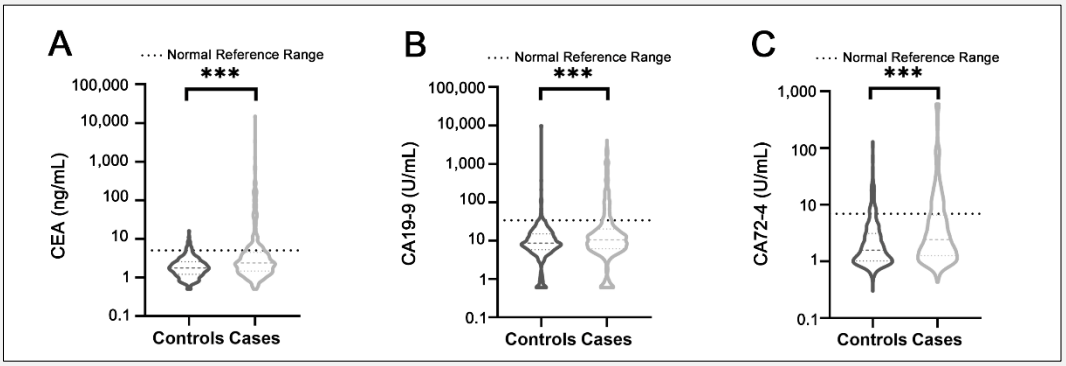
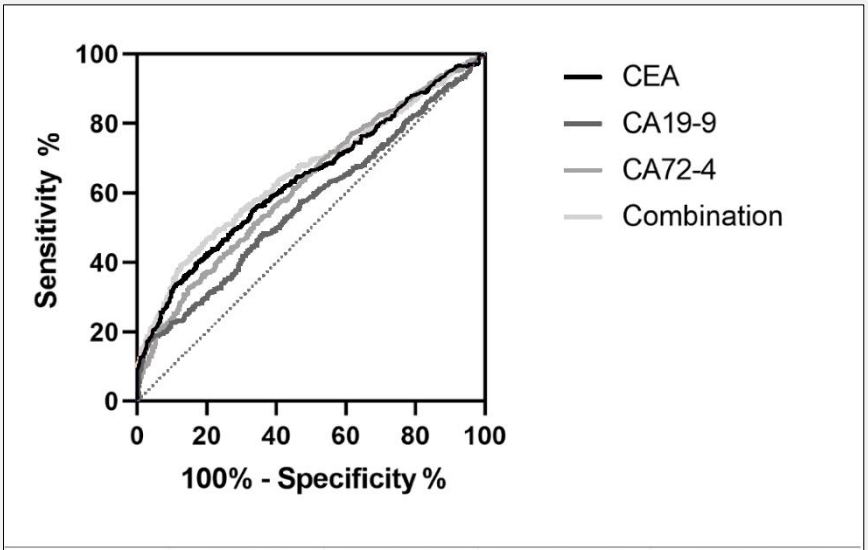


Figure 1. Expression levels of carcinoembryonic antigen (CEA), carbohydrate antigen (CA) 19-9, and CA72-4 for patients with malignant and benign gastric disease.

A) The distribution of CEA. The median (IQR) of CEA concentrations in controls and GC cases was 1.79 (1.24 - 2.59) and 2.38 (1.47 - 4.47) ng/mL.
B) The distribution of CA19-9. The median (IQR) of CA19-9 concentrations in controls and GC cases was 8.72 (5.91 - 15.17) and 10.52 (6.17 - 20.20) U/mL.
C) The distribution of CA72-4. The median (IQR) of CA72-4 concentrations in controls and GC cases was 1.58 (1.02 - 3.16) and 2.42 (1.26 - 6.58) U/mL.
***** - p < 0.001 for Mann-Whitney U test.**



	Cutoff	Sensitivity %	Specificity %	AUC (95% CI)
CEA	3.50 ng/mL	33.75	88.09	0.633 (0.600 - 0.665)
CA19-9	32.45 U/mL	17.91	96.22	0.565 (0.531 - 0.600)
CA72-4	4.77 ng/mL	32.38	85.23	0.621 (0.588 - 0.654)
Combination	-	39.15	86.93	0.652 (0.619 - 0.684)

Figure 2. Receiver operating characteristic (ROC) curves of individual biomarker and combined test.

Sensitivity and specificity were calculated using the cutoff value determined by Youden index.
AUC - area under the ROC curve.

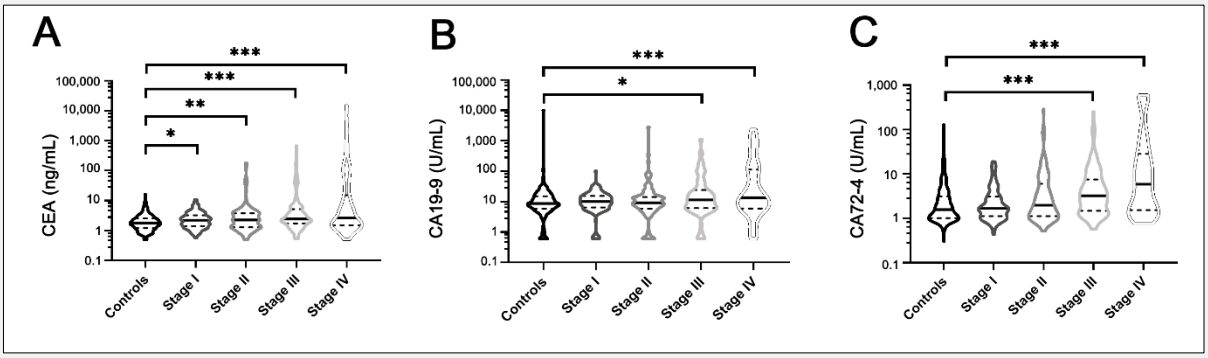


Figure 3. Expression levels of the three biomarkers in GC patients at different TNM stages.

A) The distribution of CEA at different stages.
B) The distribution of CA19-9 at different stages.
C) The distribution of CA72-4 at different stages.
*** - p < 0.05 for Kruskal-Wallis test. ** - p < 0.01 for Kruskal-Wallis test. *** - p < 0.001 for Kruskal-Wallis test.**

U/mL (1.02 - 3.16), respectively. The median concentrations (IQR) of the three biomarkers abovementioned in GC cases were 2.38 ng/mL (1.47 - 4.47), 10.52 U/mL (6.17 - 20.20), and 2.42 U/mL (1.26 - 6.58). The sensitivity and specificity at the recommended reference interval were 21.31% and 94.56% for CEA, 17.02% and 96.54% for CA19-9, and 24.02% and 89.80% for CA72-4.

In diagnostic accuracy analysis using ROC curves, CEA showed the highest AUC up to 0.633 (95% CI, 0.600 - 0.665), followed by CA72-4 (AUC, 0.621; 95% CI, 0.588 - 0.654), and CA19-9 (AUC, 0.565; 95% CI, 0.531 - 0.600). At the optimal cutoff values decided by Youden index (CEA > 3.50 ng/mL; CA19-9 > 32.45 U/mL; CA72-4 > 4.77 U/mL), the diagnostic sensitivity and specificity of the individual markers were 33.75% and 88.09% for CEA, 17.91% and 96.22% for CA19-9, and 32.38% and 85.23% for CA72-4. When combining the three biomarkers, the diagnostic efficiency was slightly improved (AUC, 0.652, 95% CI, 0.619 - 0.684, Figure 2), and the optimal sensitivity and specificity of the combination were 39.15% and 86.93%, respectively (Figure 2).

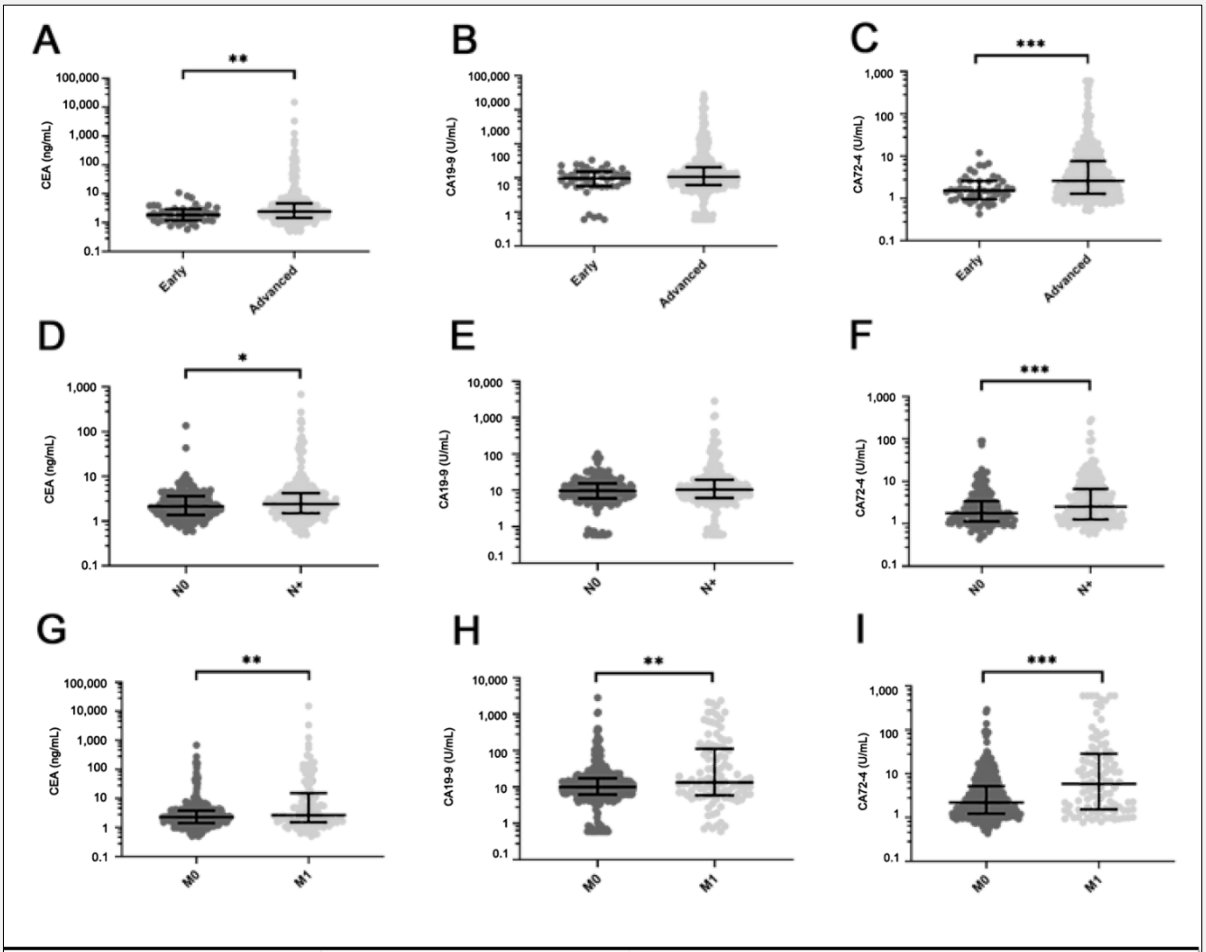
The distribution of CEA, CA19-9, and CA72-4 in different progression levels of GC

We compared the levels of CEA, CA19-9, and CA72-4 in patients with different TNM stages and differentiation grades. The levels of the three biomarkers increased incrementally with the pathological stages (all $p < 0.001$). CEA levels were upregulated GC patients of all stages (all $p < 0.05$). Regarding the results on CA19-9 and CA72-4, there was no statistically significant difference between stage I or II GC patients and controls. Significantly different results were seen between patients with stage III or IV GC and controls ($p = 0.012$ and $p < 0.001$ for CA19-9, both $p < 0.001$ for CA72-4) (Figure 3).

Besides, the levels of CEA and CA72-4 increased in patients with advanced GC, lymph node metastasis, and distant metastasis (all $p < 0.05$). The levels of CA19-9 only increased in patients with distant metastasis ($p < 0.05$). However, when the NPVs for CEA, CA19-9, and CA72-4 were set as 90%, the PPVs were modest, ranging from 19.43% to 35.29% (Figure 4). There was no significant difference related to differentiation grades.

The use of CEA, CA 19-9, and CA 72-4 for monitoring recurrence

We then enrolled 32 patients with stage II or III GC who underwent curative radical gastrectomy and received postoperative chemotherapy. Recurrence was detected in 18.8% (6 out of 32) of cases by imaging findings. No statistically significant difference in preoperative levels was observed in patients with and without the evidence of recurrence (all $p > 0.05$). For cases without recurrence, endpoint was imputed as 6 months after surgery. For cases with recurrence, endpoint was imputed as the time of recurrence identified by imaging findings. Baseline level was imputed as the lowest concentration from enrollment to endpoint. When comparing the baseline and endpoint levels of CEA, CA19-9, and CA72-4, significant differences were observed in both the recurrence and no recurrence groups. Specifically, in cases without recurrence, all p-values were less than 0.001. In cases with recurrence, the p-values were 0.028 for CEA, 0.046 for CA19-9, and 0.028 for CA72-



	Cutoff	PPV	NPV
Early/advanced			
CEA	4.10 ng/mL	28.63%	90%
CA72-4	5.03 U/mL	32.91%	
N0/N+			
CEA	4.87 ng/mL	21.05%	90%
CA72-4	9.05 U/mL	19.43%	
M0/M+			
CEA	6.60 ng/mL	33.01%	90%
CA19-9	38.60 U/mL	33.01%	
CA72-4	13.06 U/mL	35.29%	

Figure 4. The distribution of the three biomarkers in GC patients with different pathological states. (A - C): The distribution of the three biomarkers in patients with early (n = 47) and advanced GC (n = 474).

D - F): The distribution of the three biomarkers in GC patients with (n = 328) and without (n = 193) lymph node involvement.
G - I): The distribution of the three biomarkers in GC patients with (n = 103) and without (n = 413) distant metastasis.
*** - p < 0.05 for Mann-Whitney U test. ** - p < 0.01 for Mann-Whitney U test. *** - p < 0.001 for Mann-Whitney U test.**
PPV - positive predictive value, NPV - negative predictive value.

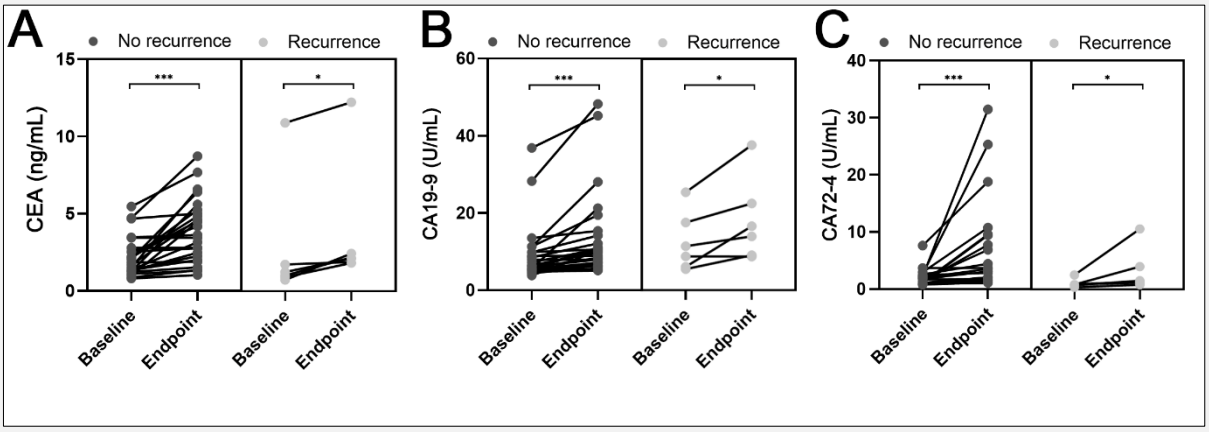


Figure 5. The baseline and endpoint levels of the three biomarkers in GC cases with or without recurrence.

A) The levels of CEA in patients with and without recurrence.
B) The levels of CA19-9 in patients with and without recurrence. C) The levels of CA72-4 in patients with and without recurrence.
Endpoint was imputed as 6 months after surgery for cases without recurrence. For cases with recurrence, endpoint was imputed as the time of recurrence identified by imaging findings.
*** - p < 0.05 for Wilcoxon signed-rank test. *** - p < 0.001 for Wilcoxon signed-rank test.**

4 (Figure 5). We calculated the absolute increase in the three biomarkers from baseline to endpoint and the median were 0.98 ng/mL, 4.27 U/mL, and 0.62 U/mL in cases with recurrence and 1.04 ng/mL, 2.62 U/mL, and 0.99 U/mL in cases without recurrence for CEA, CA19-9, and CA72-4, respectively.

DISCUSSION

This study retrospectively shows that serum concentrations of CEA, CA19-9, and CA72-4 have limited diagnostic value in GC. Combination of the three biomarkers does not improve diagnostic efficiency. Additionally, higher CEA, CA19-9, and CA72-4 concentrations portend the progression of the disease but have low PPVs.

Although significant difference was found in the levels of CEA, CA19-9, and CA72-4 between GC cases and controls, they may not be applicable for distinguishing malignant and benign gastric disease because of low sensitivity. Previous studies support our findings. At cutoff value decided by Youden Index, the diagnostic sensitivity of CEA, CA19-9, and CA72.4 in our study was 33.75%, 17.91%, and 32.38%, which was consistent with the results of previous studies reporting an optimal sensitivity of 25.5% to 38.7% for individual index [10-12]. However, the combination of the three biomarkers did not improve diagnostic efficiency, which was inconsistent with previous studies. In our study, the optimal sensitivity of the combination was only 39.15% (at 86.93% specificity). Chen et al. reported a sensitivity of 60.9% with specificity remaining at 90.5% by paralleled detection CA72-4, CEA, CA12-5, and CA19-9 in 77 patients with GC [13]. Yu, J. and W. Zheng reported a sensitivity of 75.5% by analyzing the levels of CEA, CA19-9, and CA72-4 in 216 cases of GC, including 43 patients with stage I GC, and establishing a diagnostic mathematical model using Logistic regression analysis [14]. The difference may concern the sample size and population composition. Our study included more study subjects (564 cases and 529 controls) and had a larger proportion of cases with GC at an early stage.

At present, it mainly depends on pathological stages to make treatment decisions. Endoscopic mucosal resection/endoscopic sub-mucosal dissection is recommended to perform for early GC (stage IA, T1aN0M0) patients, and patients with stage IB or above and no distant metastasis take surgery as the first choice, supplemented by radiotherapy or chemotherapy when necessary. Radiotherapy, chemotherapy, or palliative treatment is performed for advanced GC patients with distant metastasis or those unsuitable for surgery [15]. Besides, lymph node ratio has also been proposed as a novel and independent prognostic factor in GC [16]. Our study analyzed the three marker levels in different pathological stages and found that they increased incrementally with the progression of the disease. However, the PPVs for advanced GC were less than 35% when the NPVs were set as 90%, indicating that CEA and CA72-4 detections may not well distinguish patients with early and advanced GC. Similarly, these tests did

not have sufficient accuracy to predict lymph node metastasis and distant metastasis as the PPVs for each test were modest.

The follow-up surveillance after surgery for GC, including which examination to perform and how often the examinations should be performed, remains to be determined. A prospective study showed that elevated levels of CEA and CA19-9 at recurrence could be detected in more than 90% of patients with high preoperative levels and suggested that CEA and/or CA19-9 monitoring after operation was useful to predict the recurrence of GC [17]. Kim et al. reported that the false positive rate of CEA after curative radical gastrectomy for advanced GC cases was 0 [18]. However, Ohtsuka et al. reported that elevation of the levels before radiological and/or physical confirmation of recurrence was observed for 2.4% of the 168 follow-up patients, and a high frequency of false-positive findings was observed [19]. In our study, when comparing the baseline and endpoint levels of CEA, CA19-9, and CA72-4, Elevation was identical in patients with and without recurrence, indicating that detection of the biomarkers might not effectively identify tumor recurrence. The difference may concern the influence of chronic diseases including bronchitis, diabetes, hepatic dysfunction, and renal dysfunction [19]. The influence of postoperative chemotherapy may also be of concern. Besides, radiological confirmation of recurrence is lack of sensitivity. For cases with elevated biomarker levels in no recurrence group, recurrence may already have happened but not have been identified. Studies with a larger population cohort and longer follow-up observations are needed.

The current study had several limitations. First, there may be selection bias due to the retrospective design of the study. Second, we cannot eliminate the effect from prediagnostic examinations, including endoscopic biopsy and gastric care treatment, on the results of the three tumor markers. Third, due to the limited conditions of the retrospective study, we did not collect the dietary habits, living environment, and the states of Helicobacter pylori infection of the subjects and still could not explain the abnormal increased levels of CEA, CA19-9, and CA72.4 in some people who did not have tumors. Further studies are needed to explore the causes of this phenomenon.

CONCLUSION

Our retrospective study showed serum CEA, CA19-9, and CA72-4 are not applicable indexes for the differential diagnosis of patients with benign and malignant gastric disease and the combination cannot improve the diagnostic power. The levels of CEA, CA19-9, and CA72-4 increase with the progression of GC but cannot well predict advanced GC, lymph node metastasis, and distant metastasis. Further studies are needed to find out whether to take measurement of tumor makers as follow-up tests after curative radical gastrectomy.

Ethical Approval Statement:

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology (No. TJ-IRB202 11164).

Consent to Participate:

Verbal informed consent was obtained prior to the interview.We retrospectively collected clinical laboratory results of patients. The retrospective data are anonymous, and the requirement for informed consent was therefore waived.

Data Availability Statement:

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for Publication:

All the authors agreed to submit the manuscript to Clinical Laboratory.

Source of Funds:

The work was funded by the National Natural Science Foundation of China (grant No. 81572071) | recipient: Liming Cheng.

Declaration of Interest:

The authors declare that they have no conflicts of interest.

References:

1. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA Cancer J Clin 2021;71(3): 209-49. (PMID: 33538338)

2. Chen W, Zheng R, Baade PD, et al. Cancer statistics in China, 2015. CA Cancer J Clin 2016;66(2):115-32. (PMID: 26808342)

3. Ichikawa H, Yamada T, Horikoshi H, et al. X-ray diagnosis of early gastric cancer. Jpn J Clin Oncol 2010;40(9):e1-18. (PMID: 20736213)

4. Dalton WS, Friend SH. Cancer biomarkers--an invitation to the table. Science 2006;312(5777):1165-8. (PMID: 16728629)

5. Goral V, Yesilbagdan H, Kaplan A, Sit D. Evaluation of CA 72-4 as a new tumor marker in patients with gastric cancer. Hepatogastroenterology 2007;54(76):1272-5. (PMID: 17629087)

6. Joypaul B, Browning M, Newman E, Byrne D, Cuschieri A. Comparison of serum CA 72-4 and CA 19-9 levels in gastric cancer patients and correlation with recurrence. Am J Surg 1995; 169(6):595-9. (PMID: 7771623)

7. Emoto S, Ishigami H, Yamashita H, Yamaguchi H, Kaisaki S, Kitayama J. Clinical significance of CA125 and CA72-4 in gastric cancer with peritoneal dissemination. Gastric Cancer 2012; 15(2):154-61. (PMID: 21892754)

8. Jiexian J, Xiaoqin X, Lili D, et al. Clinical assessment and prognostic evaluation of tumor markers in patients with gastric cancer. Int J Biol Markers 2013;28(2):192-200. (PMID: 23787496)

9. Wang Q, Yang Y, Zhang Y-P, et al. Prognostic value of carbohydrate tumor markers and inflammation-based markers in metastatic or recurrent gastric cancer. Med Oncol 2014;31(12):289. (PMID: 25344872)

10. Hu P-J, Chen M-Y, Wu M-S, et al. Clinical Evaluation of CA72-4 for Screening Gastric Cancer in A Healthy Population: A Multicenter Retrospective Study. Cancers (Basel) 2019;11(5):733. (PMID: 31137895)

11. Yang A-P, Liu J, Lei H-Y, Zhang Q-W, Zhao L, Yang G-H. CA72-4 combined with CEA, CA125 and CAl9-9 improves the sensitivity for the early diagnosis of gastric cancer. Clin Chim Acta 2014;437:183-6. (PMID: 25086284)

12. Choi SR, Jang JS, Lee JH, et al. Role of serum tumor markers in monitoring for recurrence of gastric cancer following radical gastrectomy. Dig Dis Sci 2006;51(11):2081-6. (PMID: 17009116)

13. Chen C, Chen Q, Zhao Q, Liu M, Guo J. Value of Combined Detection of Serum CEA, CA72-4, CA19-9, CA15-3 and CA12-5 in the Diagnosis of Gastric Cancer. Ann Clin Lab Sci 2017;47(3): 260-3. (PMID: 28667025)

14. Yu J, Zheng W. An Alternative Method for Screening Gastric Cancer Based on Serum Levels of CEA, CA19-9, and CA72-4. J Gastrointest Cancer 2018;49(1):57-62. (PMID: 28028765)

15. Wang F-H, Zhang X-T, Li Y-F, et al. The Chinese Society of Clinical Oncology (CSCO): Clinical guidelines for the diagnosis and treatment of gastric cancer, 2021. Cancer Commun (Lond) 2021;41(8):747-95. (PMID: 34197702)

16. Liu J, Su M, Wang J, et al. A novel grade-lymph node ratio model predicts the prognosis of the advanced gastric cancer patients after neoadjuvant radiotherapy. Oncotarget 2017;8(8):14058-67. (PMID: 27740935)

17. Takahashi Y, Takeuchi T, Sakamoto J, et al. The usefulness of CEA and/or CA19-9 in monitoring for recurrence in gastric cancer patients: a prospective clinical study. Gastric Cancer 2003; 6(3):142-5. (PMID: 14520526)

18. Kim DH, Oh SJ, Oh CA, et al. The relationships between perioperative CEA, CA 19-9, and CA 72-4 and recurrence in gastric cancer patients after curative radical gastrectomy. J Surg Oncol 2011;104(6):585-91. (PMID: 21695697)

19. Ohtsuka T, Sato S, Kitajima Y, Tanaka M, Nakafusa Y, Miyazaki K. False-positive findings for tumor markers after curative gastrectomy for gastric cancer. Dig Dis Sci 2008;53(1):73-9. (PMID: 17476595)