Int J Clin Exp Pathol 2026;19(1):23-31
www.ijcep.com /ISSN:1936-2625/IJCEP0167510

Original Article

Caveolin-1 is upregulated in gastric cancer and is associated with tumor progression and prognosis in patients

Li-Jing Jiang[1], Shi-Ping Lu[1], Yan Wang[2], Jun-Kang Shao[1], Bi-Fei Huang[1], Chao-Qun Wang[1]

[1]Department of Pathology, Affiliated Dongyang Hospital of Wenzhou Medical University, Dongyang, Zhejiang, China; [2]Department of Medical Oncology, Affiliated Dongyang Hospital of Wenzhou Medical University, Dongyang, Zhejiang, China

Received July 16, 2025; Accepted December 2, 2025; Epub January 15, 2026; Published January 30, 2026

Abstract: Background: Although some studies have reported on the expression of caveolin-1 (CAV-1) in gastric cancer, the role and clinical importance of CAV-1 in gastric cancer are still controversial. Methods: In total, 154 paraffin-embedded gastric cancer tissue samples and 70 paired normal gastric tissue samples from the pathology department of our hospital were collected from January 2011 to December 2014. Immunohistochemistry was used to detect the expression of CAV-1 in gastric cancer and normal gastric tissue, and its relationship with various clinical pathological characteristics and the prognosis of gastric cancer was analyzed. Results: Gastric cancer tissue expressed CAV-1 in 21.4% (33/154) of cases but it was not expressed in normal gastric tissue (0%, 0/70) (P<0.001). In patients with higher T stage (T3-T4) gastric cancer, the positive rate of CAV-1 was 24.6% (31/126), which was significantly higher than that in patients with T1-T2 cancer (7.1%, 2/28) (P=0.042). Moreover, among patients with preoperatively elevated levels of the tumor biomarker carbohydrate antigen 19-9 (CA19-9) (>37 U/ml), the positivity rate for CAV-1 was 34.6% (9/26), which was significantly higher than that in patients with low CA19-9 levels (16.9%, 20/118) (P=0.042). Survival analysis revealed that compared with patients with no CAV-1 expression in their gastric tumors, patients with CAV-1 expression in their gastric tumors had lower 5-year relapse-free survival (RFS) and overall survival (OS), but the difference did not reach statistical significance (P>0.05). Multivariate analysis using a Cox proportional hazards model revealed that CAV-1 expression was an independent prognostic factor for 5-year RFS (hazard ratio=2.059, 95% confidence interval: 1.093-3.879, P=0.025) and OS (hazard ratio=1.924, 95% confidence interval: 1.002-3.696, P=0.049) in gastric cancer patients. Conclusion: High expression of CAV-1 in gastric cancer tissue is associated with poor prognosis and may be a potential biological marker for anti-gastric cancer treatment.

Keywords: Caveolin-1, CAV-1, gastric cancer, prognosis, immunohistochemistry

Introduction

Gastric cancer is among the most common malignancies worldwide. Global cancer data from 2022 revealed that its incidence ranks fifth among malignant tumors [1], while in China, gastric cancer has the third highest mortality rate, seriously affecting the population's health and safety [2]. In recent years, although significant advances have been made in the comprehensive treatment of gastric cancer, tumor recurrence and metastasis still lead to low survival rates for patients.

Caveolin-1 (CAV-1) is the main structural marker protein on the bottle-shaped vesicular structures (caveolae) that inwardly invaginate the cell membrane. It not only participates in the formation and stability of caveolae, but also interacts with various cell membrane proteins and signaling molecules, regulating multiple cellular physiological functions, including intracellular and extracellular signal transduction, cholesterol transport, cell proliferation, and tumor development [3-6]. Some studies have investigated the expression and function of CAV-1 in malignancies, reporting that CAV-1 is significantly upregulated in various tumors, such as prostate cancer, bladder cancer, liver cancer, and esophageal squamous cell carcinoma, and that it promotes tumor progression,

https://doi.org/10.62347/BMIA4742

suggesting that CAV-1 plays a procancer role [7-12]. However, other studies have shown that in tumors such as breast cancer and pancreatic cancer, high expression of CAV-1 inhibits tumor growth and invasion and plays an anticancer role [13, 14]. Therefore, CAV-1 plays a complex dual role in malignancies and has become a hot research topic.

In gastric cancer, the role of CAV-1 in inhibiting or promoting cancer is still controversial. Some studies have shown that CAV-1 inhibits the progression of gastric cancer [15], and its overexpression indicates better overall survival for gastric cancer patients [16]. However, other studies have shown that positive expression of CAV-1 promotes the progression of gastric cancer and leads to a poor prognosis [17]. In this study, the expression of CAV-1 in gastric cancer tissues was further investigated, and the relationships between its expression and various clinical pathological features and patient prognosis were analyzed. The aim of this study was to elucidate the molecular mechanisms underlying the occurrence and development of gastric cancer, and provide a valuable perspective for the diagnosis and clinical prognosis assessment of gastric cancer.

Materials and methods

Patient information and tissue samples

Paraffinized gastric cancer tissue samples from a total of 154 patients who were hospitalized and underwent surgery at our hospital from January 2011 to December 2014 were collected from the pathology department archives, along with 70 paired normal gastric paraffin tissue samples. The inclusion criterion was that a patient was diagnosed with gastric cancer by pathological diagnosis of the surgical specimen, and the participants or the participants' legal guardians/next of kin agreed to participate in the scientific research. Patients who underwent any antitumor treatment, such as targeted therapy, chemotherapy, immunotherapy, or radiotherapy, prior to surgery were excluded from this study. Histological grading was performed according to the World Health Organization (WHO) standard (5th edition, 2019). Gastric cancer patients were staged according to the American Joint Committee on Cancer (AJCC) Cancer Staging Manual, 8th edition. Among 154 cases of gastric cancer, we obtained relapse-free survival (RFS) and overall survival (OS) data for 132 and 130 gastric cancer patients, respectively. Patients were followed for a median of 60 months (range, 3-60 months). The 5-year RFS and OS rates were 53.8% and 58.5%, respectively. The study methodology adhered to the applicable guidelines and regulations set forth by the Affiliated Dongyang Hospital of Wenzhou Medical University.

Tissue array preparation

Tissue Array Preparation: We followed the methods described by Wang et al., 2020 [18]. To summarize, the Quick-ray® tissue microarray system (Cat. No.UT-06) and the Quick-ray premade recipient block (Cat. No.UB-06) wax model, both produced by Unitma Co., Ltd. in Seoul, Korea, were utilized for the preparation of tissue specimens measuring 1 mm in diameter. Two specific locations were chosen from each sample of gastric cancer tissue for sampling purposes.

IHC staining: analysis and assessment

An Envision System (Cat. No. K5007; Dako, Glostrup, Denmark) was used for IHC staining of paraffin-embedded tissue sections, following a previously described method [19, 20]. Briefly, the sections were submerged in boiling sodium citrate (pH 6.0) for 2 min in a pressure cooker. After being treated with 0.3% hydrogen peroxide for 10 min to block endogenous peroxidase activity, the sections were incubated with primary antibody overnight at 4°C. The sections were then incubated with secondary antibody for 50 min at room temperature, followed by incubation with 3,3'-diaminobenzidine (DAB) (Cat. No. K5007; Dako, Glostrup, Denmark) at room temperature. The primary antibodies used in the experiments included an anti-CAV-1 rabbit monoclonal antibody (Cat. No. ab32577; clone E249; diluted to a concentration of 1:500; obtained from Abcam, Cambridge, England). For the secondary antibody, Dako's HRP rabbit/mouse universal antibody (Cat. No. K5007; Dako, Glostrup, Denmark) was used. Criteria for CAV-1 staining assessment: CAV-1 staining was primarily localized to the cell membrane, with some cytoplasmic staining observed. In this study, positive staining was defined as ≥1% of cancer cells or normal gastric mucosal glandular epithelial cells exhibiting either intact or partial cell mem-

brane staining [21]. The interpretation of the staining results was independently completed by two pathologists. If the results from the two pathologists were not consistent, a third pathologist evaluated and determined the final score.

Patient follow-up

Patients were followed up using previously described methods [18, 22]. In brief, patients entered follow-up after surgery, with a check-up every six months. Local recurrence or distant metastasis of gastric cancer was diagnosed through clinical imaging or pathological histology. Follow-up was conducted through telephone after surgery, with a 6-month interval between each follow-up. Follow-up was terminated if the patient died. RFS was defined as the time from surgery to relapse/metastasis and OS was defined as the time from surgery to death (excluding non-tumor-related deaths).

Statistical analysis

Data processing was conducted using SPSS 23.0 analysis software (SPSS Inc., Chicago, IL, USA). Categorical data were expressed as proportions or rates, and continuous data were presented as mean ± standard deviation (x ± S). Group comparisons for categorical variables were performed using the chi-square test, while continuous data were analyzed using the t-test or one-way ANOVA. The chi-square test was used to analyze the differences in CAV-1 protein expression between groups and the relationship between CAV-1 expression and the clinical pathological characteristics of patients. The Kaplan-Meier method was used to calculate the OS and RFS rates of gastric cancer patients. The log-rank test was used to analyze the differences in survival curves between different CAV-1 expression groups. Survival curves were plotted using GraphPad Prism software (GraphPad software Inc., San Diego, CA, USA). A Cox proportional hazards model (input method) was used to analyze the independent prognostic factors of gastric cancer patients. A *P*-value of less than 0.05 was considered to indicate statistical significance.

Results

Clinicopathological characteristics and CAV-1 expression in gastric cancer

There were 105 male patients and 49 female patients with gastric cancer; their ages ranged from 37 to 86 years, with a median age of 68 years. The histological grade ranged from well to moderately differentiated in 72 patients and poorly differentiated in 82 patients; and the pTNM stage was stage I in 14 patients, stage II in 31 patients, stage III in 103 patients, and stage IV in 6 patients. The other clinical and pathological characteristics and grouping details are listed in **Table 1**. Among them, body mass index (BMI) information was missing for 3 patients; preoperative blood tumor marker carcinoembryonic antigen (CEA) and carbohydrate antigen 19-9 (CA19-9) data were missing for 10 patients; and carbohydrate antigen 72-4 (CA72-4) data were available for 72 patients but were missing for 82 patients.

Among the 154 cases of gastric cancer tissue samples, 33 were CAV-1 positive (21.4%, 33/154), while the CAV-1 positivity rate in 70 normal gastric tissue samples was 0.0% (0/70) (**Table 2**). The CAV-1 positivity rate in gastric cancer tissues was significantly higher than that in normal gastric tissues ($P<0.001$) (**Figure 1**).

Relationship between CAV-1 expression and clinical pathological features of gastric cancer

As shown in **Table 1**, the positivity rate of CAV-1 in patients with T3-T4 stage gastric cancer was 24.6% (31/126), while the CAV-1 positivity rate in patients with T1-T2 stage was 7.1% (2/28), with a statistically significant difference between the two groups ($P=0.042$). Moreover, among patients with preoperatively elevated levels of the tumor biomarker CA19-9 (>37 U/ml), the positivity rate for CAV-1 was 34.6% (9/26), while the CAV-1 positivity rate in patients with low CA19-9 levels was 16.9% (20/118), with a statistically significant difference also observed between the two groups ($P=0.042$). CAV-1 expression was not associated with gender, age, histological grade, tumor size, Lauren classification, lymph node metastasis, smoking status, alcohol consumption, BMI or other characteristics in gastric cancer patients.

Relationship between CAV-1 expression and prognosis in gastric cancer patients

Survival analysis revealed that the 5-year average RFS period for CAV-1 positive gastric cancer patients was 32.9 months, with anRFS rate of 43.3% (13/30), which was lower than that for

Table 1. Association of CAV-1 expression with clinicopathological parameters in gastric cancer patients

Variables	No. of patients	CAV-1 negative, n (%)	CAV-1 positive, n (%)	χ^2	*P*-value*
Gender					
Male	105	79 (75.2)	26 (24.8)	2.178	0.140
Female	49	42 (85.7)	7 (14.3)		
Age (years)					
≤60	34	29 (85.3)	5 (14.7)	1.171	0.279
>60	120	92 (76.7)	28 (23.3)		
Tumor size (cm)					
≤5	93	72 (77.4)	21 (22.6)	0.185	0.667
>5	61	49 (80.3)	12 (19.7)		
Tumor differentiation					
High-Moderate	72	58 (80.6)	14 (19.4)	0.316	0.574
Poor	82	63 (76.8)	19 (23.2)		
Lauren classification					
Intestinal	106	84 (79.2)	22 (20.8)	1.493	0.474
Mixed	19	13 (68.4)	6 (31.6)		
Diffuse	29	24 (82.8)	5 (17.2)		
T stage					
T1-T2	28	26 (92.9)	2 (7.1)	4.148	**0.042**
T3-T4	126	95 (75.4)	31 (24.6)		
Lymph node metastases					
No	33	28 (84.8)	5 (15.2)	0.983	0.321
Yes	121	93 (76.9)	28 (23.1)		
Tumor stage					
I-II	45	39 (86.7)	6 (13.3)	2.475	0.116
III-IV	109	82 (75.2)	27 (24.8)		
Smoke					
No	71	58 (81.7)	13 (18.3)	0.761	0.383
Yes	83	63 (75.9)	20 (24.1)		
Drink					
No	93	73 (78.5)	20 (21.5)	0.001	0.977
Yes	61	48 (78.7)	13 (21.3)		
BMI					
<18.5	23	18 (78.3)	5 (21.7)	2.583	0.275
18.5-23.9	97	79 (81.4)	18 (18.6)		
>23.9	31	21 (67.7)	10 (32.3)		
CEA (ng/ml)					
≤5	110	85 (77.3)	25 (22.7)	1.941	0.164
>5	34	30 (88.2)	4 (11.8)		
CA19-9 (U/ml)					
≤37	118	98 (83.1)	20 (16.9)	4.134	**0.042**
>37	26	17 (65.4)	9 (34.6)		

CA72-4 (U/ml)					
≤6.9	58	46 (79.3)	12 (20.7)	0.078	0.781
>6.9	14	10 (71.4)	4 (28.6)		

*Pearson's chi-square test was used for the comparison of the CAV-1positive expression rate among different groups. A bold value of $P<0.05$ indicates statistical significance. Abbreviations: CAV-1 = caveolin-1; BMI = body mass index; CEA = carcinoembryonic antigen; CA19-9 = carbohydrate antigen 19-9; CA72-4 = carbohydrate antigen 72-4.

Table 2. CAV-1 expression in gastric tissue specimens

Tissue samples	No.	CAV-1 expression		χ^2	*P*-value
		Negative, n (%)	Positive, n (%)		
Noncancerous	70	70 (100.0%)	0 (0.0%)	17.592	<0.001
Cancerous	154	121 (78.6%)	33 (21.4%)		

Abbreviation: CAV-1 = caveolin-1.

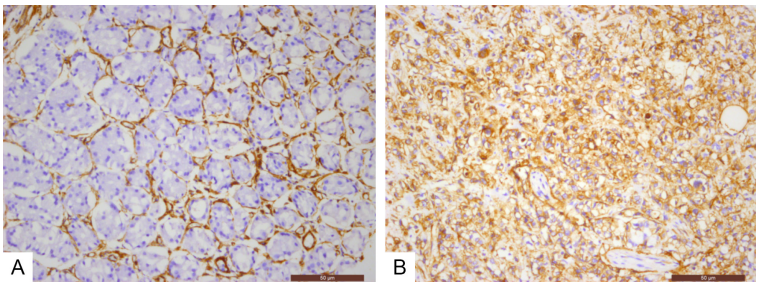

Figure 1. Immunochemical analysis of caveolin-1 (CAV-1) expression in gastric tissues. A. Normal gastric tissue with negative expression of CAV-1 in gastric glandular epithelial cells (200× magnification). B. Gastric cancer tissue with positive CAV-1 expression in cancer cells (200× magnification).

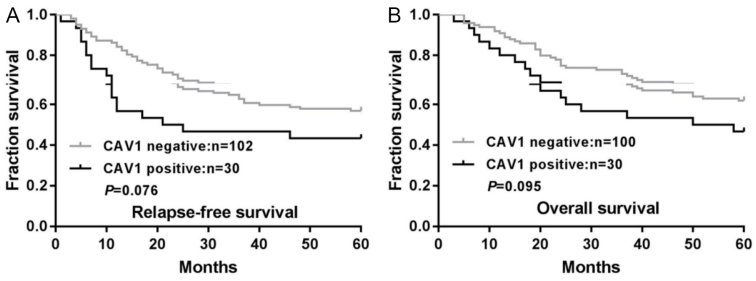

Figure 2. Associations between caveolin-1 (CAV-1) expression and the survival of patients with gastric cancer. Associations of CAV-1 expression with relapse-free survival (RFS) (A) and overall survival (OS) (B) were analyzed in the gastric cancer cohort. *P*-values were calculated using the Mantel-Cox log-rank test.

CAV-1 negative gastric cancer patients [5-year average RFS period of 42.5 months, RFS rate of 56.9% (58/102)], but the difference was not significant (P=0.076) (**Figure 2A**).

The 5-year average survival period for CAV-1 positive gastric cancer patients was 39.3 months, with an OS rate of 46.7% (14/30), which was lower than that for CAV-1 negative gastric cancer patients [5-year average survival period of 46.3 months, OS rate of 62.0% (62/100)], but the difference was not significant (P=0.095) (**Figure 2B**).

Multivariate Cox proportional hazards model analysis revealed that CAV-1 expression was an independent prognostic factor associated with poor prognosis for both 5-year RFS (HR=2.059, 95% CI=1.093-3.879, P=0.025) and OS (HR=1.924, 95% CI=1.002-3.696, P=0.049) (**Table 3**).

Discussion

CAV-1 is the main structural protein and marker protein on the vesicle structure (caveolae) with a bottleneck shape recessing inwardly in the cell membrane and a diameter of approximately 50-100 nm [3, 4]. Studies have shown that CAV-1 is involved in various physiological functions of human cells, including transmembrane substance transport, cell phagocytosis, lipid homeostasis, intracellular cholesterol transport, and signal transduction [3-6]. The gene encoding human CAV-1 is located at a known fragile site (FRA7G) D7S522 locus (7q31.1), which is frequently deleted in human cancers, including head and neck squamous cell carcinoma, prostate cancer, renal cell carcinoma, ovarian adenocarcinoma, colon cancer, and breast cancer, suggesting a close relationship between CAV-1 and tumorigenesis [23]. Previous studies have indicated that CAV-1 plays a dual role in malignant tumors, acting either as a promoter or inhibitor

Table 3. Multivariate Cox regression analysis for RFS and OS according to clinicopathological information and CAV-1 status

Variables	RFS					OS				
	B	SE	Wald	HR (95% CI)	*P*-value*	B	SE	Wald	HR (95% CI)	*P*-value*
CAV-1 (positive vs. negative)	0.722	0.323	4.990	2.059 (1.093-3.879)	**0.025**	0.655	0.333	3.864	1.924 (1.002-3.696)	**0.049**
Age (>60 vs. ≤60)	0.715	0.386	3.435	2.045 (0.960-4.358)	0.064	0.727	0.415	3.063	2.069 (0.917-4.669)	0.080
Gender (female vs. male)	0.333	0.487	0.467	1.395 (0.537-3.621)	0.494	0.616	0.522	1.394	1.851 (0.666-5.148)	0.238
Tumor differentiation (poor vs. high-moderate)	0.587	0.345	2.901	1.799 (0.915-3.538)	0.089	0.692	0.370	3.507	1.998 (0.968-4.124)	0.061
Tumor size (>5 cm vs. ≤5 cm)	0.233	0.275	0.717	1.263 (0.736-2.166)	0.397	0.090	0.295	0.094	1.095 (0.613-1.953)	0.760
Lauren classification (Mixed vs. Intestinal)	-1.017	0.572	3.158	0.362 (0.118-1.110)	0.076	-0.779	0.574	1.838	0.459 (0.149-1.415)	0.175
Lauren classification (Diffuse vs. Intestinal)	0.584	0.400	2.137	1.794 (0.819-3.927)	0.144	0.543	0.425	1.638	1.722 (0.749-3.957)	0.201
Lymph node metastases (Yes vs. No)	0.783	0.665	1.389	2.189 (0.595-8.051)	0.239	0.687	0.743	0.854	1.987 (0.463-8.524)	0.355
T stage (T3-T4 vs. T1-T2)	-0.455	0.684	0.443	0.634 (0.166-2.424)	0.506	-0.705	0.680	1.076	0.494 (0.130-1.873)	0.300
Tumor stage (III-IV vs. I-II)	1.003	0.803	1.561	2.728 (0.565-13.165)	0.211	1.494	0.849	3.098	4.454 (0.844-23.504)	0.078
Smoke (Yes vs. No)	0.310	0.430	0.519	1.363 (0.587-3.168)	0.471	0.407	0.461	0.780	1.503 (0.609-3.712)	0.377
Drink (Yes vs. No)	0.014	0.340	0.002	1.015 (0.521-1.977)	0.966	0.140	0.361	0.150	1.150 (0.566-2.335)	0.699
BMI (18.5-23.9 vs. <18.5)	0.281	0.432	0.423	1.324 (0.568-3.086)	0.515	0.309	0.458	0.456	1.362 (0.555-3.339)	0.500
BMI (>23.9 vs. <18.5)	-0.584	0.558	1.097	0.558 (0.187-1.663)	0.295	-0.534	0.574	0.864	0.586 (0.190-1.807)	0.353

*A bold value of $P<0.05$ indicates statistical significance. Abbreviations: CAV-1 = caveolin-1; BMI = body mass index; RFS = relapse-free survival; OS = overall survival; B = coefficient estimate; SE = standard error; Wald = Wald statistic; HR = hazard ratio; 95% CI = 95% confidence interval.

of cancer [7-14]. For example, it has been reported to be upregulated in tumors such as prostate cancer and bladder cancer, promoting tumor progression [7-12], whereas in breast cancer and pancreatic cancer, its high expression has been shown to inhibit tumor growth and invasion, exerting an anticancer effect [13, 14].

The role of CAV-1 in the occurrence and development of gastric cancer and the prediction of patient outcomes is also controversial. Some studies suggest that CAV-1 inhibits the progression of gastric cancer and is associated with better overall survival of gastric cancer patients [15, 16]. However, other studies suggest that expression of CAV-1 promotes the progression of gastric cancer and is associated with poor prognosis [17]. Burgermeister et al. proposed the "CAV-1 + companion protein X" concept to explain its dual role: CAV-1 interacts via its CSD domain. When it interacts with beneficial proteins, it maintains tissue homeostasis; when it interacts with tumor-promoting proteins, it promotes cancer progression [24]. Additionally, posttranslational modifications (e.g., tyrosine or serine phosphorylation) alter CAV-1 function, enhancing tumor growth or survival [25, 26].

To further elucidate the role and clinical value of CAV-1 in gastric cancer, we used immunohistochemistry to detect the expression of CAV-1 in gastric cancer and normal gastric tissues. We found that the expression of CAV-1 in gastric cancer tissues significantly deviated from that in normal gastric tissues, where it was entirely absent. These findings highlight the potential of CAV-1 as a biomarker for the presence of gastric cancer. Furthermore, in our analysis, CAV-1 expression was notably higher in individuals with advanced T stages (T3-T4), suggesting its involvement in tumor progression. Moreover, the positive correlation between CAV-1 and CA19-9, a marker often associated with aggressive disease and poor prognosis [27-30], further supports the potential role of CAV-1 in enhancing tumor invasiveness and metastatic tendency. Clinically, the combined detection of CAV-1 and CA19-9 may help identify a subgroup of patients with more biologically aggressive tumors who might benefit from intensified treatment or closer monitoring. This association with tumoral aggression might help elucidate mechanisms of tumor biology specific to gastric cancer. Notably, CAV-1 expression was not correlated with other clinical pathological features, such as age, gender, or histological grade, indicating that its involvement may be isolated to specific aspects of cancer progression rather than broad oncogenic processes.

In terms of prognosis, while our findings indicate that compared with their CAV-1 negative counterparts, CAV-1 positive patients had lower 5-year RFS and OS rates, these differences did not reach statistical significance in the univariate analysis. This could be attributed to the relatively small number of CAV-1 positive patients, which may have limited the ability to detect a statistically significant correlation with survival. Despite this limitation, further analysis using the Cox proportional hazards model revealed that CAV-1 positivity is an independent prognostic factor, underscoring its potential role in predicting clinical outcomes in patients with gastric cancer.

In summary, the expression of CAV-1 is clinically significant in gastric cancer, particularly in relation to disease progression and prognosis. However, the limitations of this study include the small sample size of CAV-1 positive patients, which restricts comprehensive statistical analysis. Future research should aim to include larger, more diverse populations to confirm these findings and understand the underlying biological mechanisms. The development of targeted therapies that consider CAV-1 expression has the potential to improve gastric cancer treatment strategies and patient management.

Acknowledgements

This work was supported by a grant from the Science and Technology Project of Dongyang City (22-301).

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Chao-Qun Wang, Department of Pathology, Affiliated Dongyang Hospital of Wenzhou Medical University, 60 Wu Ning Xi Road, Dongyang, Zhejiang, China. E-mail: chaoqunw869@163.com

References

[1] Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I and Jemal A. Global can-

cer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 2024; 74: 229-263.
[2] Zheng RS, Chen R, Han BF, Wang SM, Li L, Sun KX, Zeng HM, Wei WW and He J. Cancer incidence and mortality in China, 2022. Zhonghua Zhong Liu Za Zhi 2024; 46: 221-231.
[3] Couet J, Li S, Okamoto T, Ikezu T and Lisanti MP. Identification of peptide and protein ligands for the caveolin-scaffolding domain. Implications for the interaction of caveolin with caveolae-associated proteins. J Biol Chem 1997; 272: 6525-6533.
[4] Razani B, Woodman SE and Lisanti MP. Caveolae: from cell biology to animal physiology. Pharmacol Rev 2002; 54: 431-467.
[5] Chintalaramulu N, Singh DP, Sapkota B, Raman D, Alahari S and Francis J. Caveolin-1: an ambiguous entity in breast cancer. Mol Cancer 2025; 24: 109.
[6] Lai X, Guo Y, Chen M, Wei Y, Yi W, Shi Y and Xiong L. Caveolin1: its roles in normal and cancer stem cells. J Cancer Res Clin Oncol 2021; 147: 3459-3475.
[7] Thompson TC, Tahir SA, Li L, Watanabe M, Naruishi K, Yang G, Kadmon D, Logothetis CJ, Troncoso P, Ren C, Goltsov A and Park S. The role of caveolin-1 in prostate cancer: clinical implications. Prostate Cancer Prostatic Dis 2010; 13: 6-11.
[8] Raja SA, Shah STA, Tariq A, Bibi N, Sughra K, Yousuf A, Khawaja A, Nawaz M, Mehmood A, Khan MJ and Hussain A. Caveolin-1 and dynamin-2 overexpression is associated with the progression of bladder cancer. Oncol Lett 2019; 18: 219-226.
[9] Tse EY, Ko FC, Tung EK, Chan LK, Lee TK, Ngan ES, Man K, Wong AS, Ng IO and Yam JW. Caveolin-1 overexpression is associated with hepatocellular carcinoma tumourigenesis and metastasis. J Pathol 2012; 226: 645-653.
[10] Ando T, Ishiguro H, Kimura M, Mitsui A, Mori Y, Sugito N, Tomoda K, Mori R, Harada K, Katada T, Ogawa R, Fujii Y and Kuwabara Y. The overexpression of caveolin-1 and caveolin-2 correlates with a poor prognosis and tumor progression in esophageal squamous cell carcinoma. Oncol Rep 2007; 18: 601-609.
[11] Zhang T, Yu M, Tang T, Zhao Y, Liu M and Zhang P. Caveolin-1 in prostate cancer: novel insights and therapeutic opportunities-a review. Int J Biol Macromol 2025; 319: 145410.
[12] Kabir TD, Beck S, Stuart LM, Li J, Hou R, Liu P, Margolius S, Kim C, Choi YS, Bastow ER, Beveridge DJ, Spalding L, Li Z, Ginhoux F, Chow P, Phillips M and Redfern AD; Liver Cancer Collaborative; Yeoh GC, Forrest A, Woo AJ, Sharma A, George J, McCaughan G and Leedman PJ. Inhibition of the Caveolin-1 pathway promotes apoptosis and overcomes pan-tyrosine kinase inhibitor resistance in hepatocellular carcinoma. Cell Death Dis 2025; 16: 561.
[13] Bouras T, Lisanti MP and Pestell RG. Caveolin-1 in breast cancer. Cancer Biol Ther 2004; 3: 931-941.
[14] Han F and Zhu HG. Over-expression of caveolin-1 inhibits proliferation and invasion of pancreatic carcinoma cells in vitro. Zhonghua Zhong Liu Za Zhi 2009; 31: 732-737.
[15] Zhang K, Yang G, Wu W, Zhang J, Xia X, Jiang T, Cao J, Huang K, Qiu Z and Huang C. Decreased expression of caveolin-1 and E-cadherin correlates with the clinicopathologic features of gastric cancer and the EMT process. Recent Pat Anticancer Drug Discov 2016; 11: 236-244.
[16] Ye Y, Miao SH, Lu RZ and Zhou JW. Prognostic value of caveolin-1 expression in gastric cancer: a meta-analysis. Asian Pac J Cancer Prev 2014; 15: 8367-8370.
[17] Seker M, Aydin D, Bilici A, Yavuzer D, Ozgun MG, Ozcelik M, Aydin O and Aliustaoglu M. Correlation of caveolin-1 expression with prognosis in patients with gastric cancer after gastrectomy. Oncol Res Treat 2017; 40: 185-190.
[18] Wang CQ, Wang Y, Huang BF, Tang CH, Du Z, Zeng Y, Wang Q, Shao JK and Jin LL. High expression of both resistin and fascin-1 predicts a poor prognosis in patients with colorectal cancer. Biomed Res Int 2020; 2020: 8753175.
[19] Wang CQ, Tang CH, Chang HT, Li XN, Zhao YM, Su CM, Hu GN, Zhang T, Sun XX, Zeng Y, Du Z, Wang Y and Huang BF. Fascin-1 as a novel diagnostic marker of triple-negative breast cancer. Cancer Med 2016; 5: 1983-1988.
[20] Wang CQ, Li Y, Huang BF, Zhao YM, Yuan H, Guo D, Su CM, Hu GN, Wang Q, Long T, Wang Y, Tang CH and Li X. EGFR conjunct FSCN1 as a novel therapeutic strategy in triple-negative breast cancer. Sci Rep 2017; 7: 15654.
[21] Wang Y, Wang Q, Tang CH, Chen HD, Hu GN, Shao JK, Dong XF, Jin LL and Wang CQ. p-STAT3 expression in breast cancer correlates negatively with tumor size and HER2 status. Medicine (Baltimore) 2021; 100: e25124.
[22] Dong XF, Wang Y, Huang BF, Hu GN, Shao JK, Wang Q, Tang CH and Wang CQ. Downregulated METTL14 expression correlates with breast cancer tumor grade and molecular classification. Biomed Res Int 2020; 2020: 8823270.
[23] Engelman JA, Zhang XL and Lisanti MP. Genes encoding human caveolin-1 and -2 are co-localized to the D7S522 locus (7q31.1), a known fragile site (FRA7G) that is frequently deleted in human cancers. FEBS Lett 1998; 436: 403-410.
[24] Burgermeister E, Liscovitch M, Rocken C, Schmid RM and Ebert MP. Caveats of caveo-

lin-1 in cancer progression. Cancer Lett 2008; 268: 187-201.
[25] Lee H, Volonte D, Galbiati F, Iyengar P, Lublin DM, Bregman DB, Wilson MT, Campos-Gonzalez R, Bouzahzah B, Pestell RG, Scherer PE and Lisanti MP. Constitutive and growth factor-regulated phosphorylation of caveolin-1 occurs at the same site (Tyr-14) in vivo: identification of a c-Src/Cav-1/Grb7 signaling cassette. Mol Endocrinol 2000; 14: 1750-1775.
[26] Tahir SA, Yang G, Ebara S, Timme TL, Satoh T, Li L, Goltsov A, Ittmann M, Morrisett JD and Thompson TC. Secreted caveolin-1 stimulates cell survival/clonal growth and contributes to metastasis in androgen-insensitive prostate cancer. Cancer Res 2001; 61: 3882-3885.
[27] So SW, Han JH, Yuk HD, Jeong CW, Kwak C, Ku JH and Jeong SH. High carbohydrate antigen 19-9 levels indicate poor prognosis in patients with bladder cancer following radical cystectomy. Front Oncol 2025; 15: 1550203.
[28] Luo G, Jin K, Deng S, Cheng H, Fan Z, Gong Y, Qian Y, Huang Q, Ni Q, Liu C and Yu X. Roles of CA19-9 in pancreatic cancer: biomarker, predictor and promoter. Biochim Biophys Acta Rev Cancer 2021; 1875: 188409.
[29] Gao Y, Wang J, Zhou Y, Sheng S, Qian SY and Huo X. Evaluation of Serum CEA, CA19-9, CA72-4, CA125 and ferritin as diagnostic markers and factors of clinical parameters for colorectal cancer. Sci Rep 2018; 8: 2732.
[30] Jeong SH, Han JH, Jeong CW, Kim HH, Kwak C, Yuk HD and Ku JH. High carbohydrate antigen 19-9 levels indicate poor prognosis of upper tract urothelial carcinoma. Front Oncol 2022; 12: 858813.