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Prevalence of *Helicobacter pylori* infection in the general population in Wuzhou, China: a cross-sectional study

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Abstract

Background *Helicobacter pylori* (*H. pylori*) is a global infectious carcinogen. We aimed to evaluate the prevalence of *H. pylori* infection in the healthcare-utilizing population undergoing physical examinations at a tertiary hospital in Guangxi, China. Furthermore, gastroscopies were performed on selected participants to scrutinize the endoscopic features of *H. pylori* infection among asymptomatic individuals.

Subjects and methods This study involved 22,769 participants who underwent *H. pylori* antibody serology screenings at the hospital between 2020 and 2023. The 14C-urea breath test was employed to determine the current *H. pylori* infection status of 19,307 individuals. Concurrently, 293 participants underwent gastroscopy to evaluate their endoscopic mucosal abnormalities. The risk correlation and predictive value of endoscopic mucosal traits, Hp infection status, and 14C-urea breath test(14C-UBT) outcomes were investigated in subsequent analyses.

Results Serum Ure, CagA, and VacA antibodies were detected in 43.3%, 27.4%, and 23.6% of the 22,769 subjects that were screened, respectively. The population exhibited 27.5% and 17.2% positive rates for immune type I and II, respectively. Male participants exhibited lower positive rates of serum antibodies than females. The positive rates and predictive risks of the antibodies increased with age, and the highest positive rates were observed in the 50–60 age subgroup. Based on the outcomes of serological diagnostic techniques, it was observed that the positive rate was significantly higher compared to that of non-serological diagnostic methods, specifically the 14C-UBT results (43.3% versus 14.97%). Among the other cohort ($n = 19{,}307$), the 14C-UBT revealed a 14.97% positivity rate correlated with age. The 293 individuals who underwent gastroscopy from 14C-UBT Cohort were found to be at an increased risk of a positive breath test if they exhibited duodenal bulb inflammation, diffuse redness, or mucosal edema during the gastroscopy visit.

Conclusion The prevalence of *Helicobacter pylori* infection is high among the population of Wuzhou, Guangxi, China. Type I *H. pylori* strains, distinguished by their enhanced virulence, are predominant in this region. In the framework of

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this population-based study, age has been identified as an independent risk factor for *H. pylori* infection. Additionally, distinct mucosal manifestations observed during gastroscopy can facilitate the identification of healthcare-utilizing individuals with active *H. pylori* infections.

Keywords *Helicobacter pylori*, Affected population, Serological screening, Gastric mucosa, Endoscopy

Introduction

Helicobacter pylori (*H. pylori*), a globally widespread bacterial pathogen, typically colonizes the gastric mucosal tissue. This infection primarily induces chronic active inflammation, which can progress to chronic non-atrophic gastritis, atrophic gastritis, and peptic ulcer diseases. Furthermore, it significantly increases the risk of gastric cancer and gastric mucosa-associated lymphoid tissue lymphoma [1–3]. Because of its carcinogenic potential, the World Health Organization has classified *H. pylori* as a Group 1 carcinogen, with a global prevalence estimated at approximately 50%. The infection rates of *H. pylori* vary across different demographics and geographical regions, with higher incidence rates observed in developing countries than in developed ones. Nationally, the *H. pylori* infection rate is 44.2%, affecting approximately 589 million individuals in China [4–7]. This prevalence increases with age, increasing from 28.0% among children and adolescents to 46.1% in adults [7–10].

Recent progress in medical and health standards has resulted in a decreasing trend in the overall prevalence of *H. pylori* in China. Most infected individuals are asymptomatic carriers. However, almost all *H. pylori*-infected persons, whether symptomatic or asymptomatic, exhibit histologically chronic active inflammation in their gastric mucosa. *H. pylori* continues to pose a significant global health risk and disease burden due to the lack of effective vaccines, emerging antibiotic resistance, and the impact of this persistent infection on cancer incidence. Therefore, it is essential to research *H. pylori* infection to enhance the effectiveness of current and future local health prevention and control strategies.

This study focused on the epidemiological analysis of *H. pylori* infection in Wuzhou, Guangxi, over four years between January 2020 and December 2023. The aim is to utilize the findings of this research to develop effective strategies for the prevention and treatment of *H. pylori* in Guangxi. Additionally, it is anticipated that the results will assist in detecting *H. pylori* infection in individuals undergoing endoscopy during routine physical examinations. Thus, it provides a valuable guide for enhancing the diagnostic and therapeutic capabilities of primary care physicians in managing *H. pylori* infection.

Materials and methods

Study population

The study recruited participants who underwent *H. pylori* testing at the healthcare center of Wuzhou Red Cross Hospital between January 2020 and December 2023, and who were capable of providing comprehensive baseline and clinical data. Further exclusion criteria were imposed on individuals undergoing the urea breath test (UBT) and gastroscopy. Notably, there was no overlap between the 22,769 participants who underwent antibody serology screening and the 19,307 healthy controls included in the study. These exclusions encompassed individuals aged ≥ 75, those who had undergone previous gastrointestinal surgeries, including gastrectomy, patients with a history of acute myocardial infarction in the preceding six months, severe organ dysfunction, mental illness, and the use of antibiotics or bismuth preparations in the last four weeks, or the administration of proton pump inhibitors, non-steroidal drugs, and other gastrointestinal medications in the fortnight preceding the examination. Determination of the *H. pylori* infection type was achieved through the 14C-UBT or serological testing(Fig. 1).

Ethics statement

This study was approved by the Ethics Committee of Wuzhou Red Cross Hospital. Before participation, all subjects provided written informed consent, acknowledging that all procedures would adhere strictly to established standards.

Serological assays

The *H. pylori* antibody typing detection kit (10716, ISIA Biotech Co., Ltd.), utilizing a fluorescence immunoassay technique, was employed in the present study. Prior to testing, both the test cards and samples were allowed to equilibrate at room temperature. After verifying that the card was compatible with the kit's batch number, a precise aliquot of 80 μL of the sample was carefully dispensed into the designated sample well in a vertical manner. Subsequently, the analyzer proceeded to detect and interpret the test results. The absence of *H. pylori* antibodies (cytotoxin-associated gene A [CagA], urease [Ure], vacuolating cytotoxin A [VacA]) indicated no previous infection, while the presence of any such antibody, regardless of previous anti-*H. pylori* therapy was indicative of past infection. Serological immune typing was ascertained based on the expression of specific antibodies: positivity for CagA or VacA antibodies denoted Type I infection, whereas exclusive positivity for the Ure antibody denoted Type II.

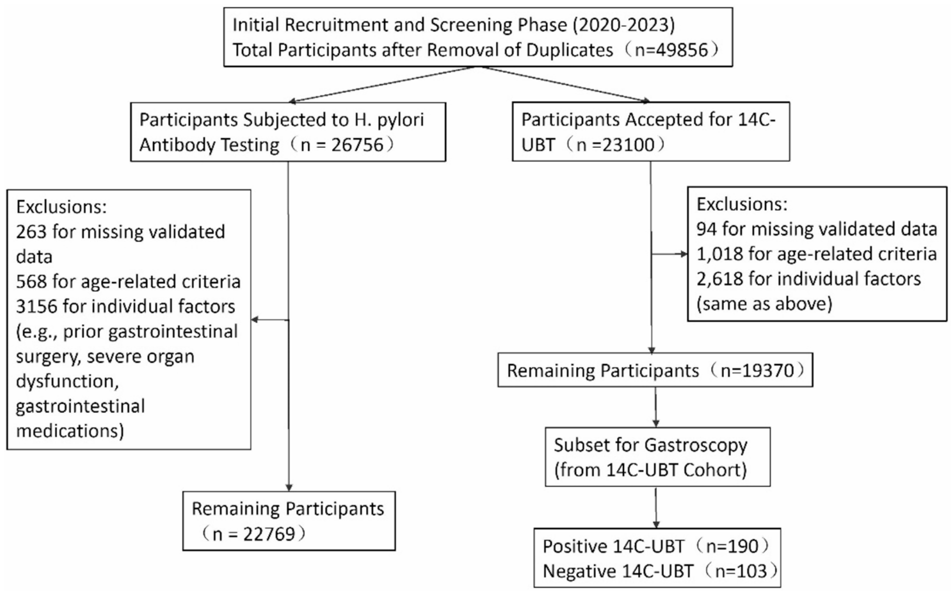

Fig. 1 Flow chart of the study

Urea breath analysis

The carbon-14 (^{14}C) UBT (HUBT-20P, Headway Biotech Co., Ltd.) was utilized to assess the status of *H. pylori* infection. A positive test result was indicative of active *H. pylori* colonization. Following a 15-minute quiet waiting period, they *exhaled* through a blowpipe into a collection card until the color indicator within the card's window shifted from orange-red to yellow. This exhalation process typically lasted between 1 and 3 min. The entire procedure, including the administration, supervision, and interpretation of the breath test results, was conducted by qualified medical personnel.

Gastric endoscopy examination

Subjects were required to abstain from food intake for 6 h before undergoing the endoscopic procedure. The endoscope (H290Z, Olympus Corporation, Tokyo, Japan) was inserted through the oral cavity to examine various mucosal features comprehensively. These included the assessment of mucosal hue, texture, mucus secretion, peristaltic activity, and luminal anatomy commencing from the upper esophagus. The precise locations, extents, and specific features of any detected lesions, such as gastric or duodenal ulcers, were meticulously documented. Two qualified endoscopists with over five years of experience observed, documented, and evaluated the endoscopic images.

Statistical analysis

Statistical Package for the Social Sciences software (version 23.0) and R software (version 4.2.2) were utilized for data analysis. Quantitative data are presented as mean ± standard deviation, while categorical variables are presented as frequency (count) and percentage. The chi-square test and Fisher's exact test were used for group comparison. Analysis of variance and the t-test were employed for qualitative data with a normal distribution and homogenous variance. Conversely, the non-parametric rank-sum test was utilized for quantitative data that did not adhere to a normal distribution. Variables that reached a significance level of $P < 0.1$ underwent further examination within a logistic regression model. $P \leq 0.05$ was considered statistically significant.

Results

Basic analysis of *H. pylori* antibody detection

The Wuzhou Red Cross Hospital healthcare center processed 22,769 blood samples between 2020 and 2023 for *H. pylori* antibody testing. The comprehensive analysis revealed the following positivity rates for Ure, CagA, and VacA antibodies: 43.3%, 27.4%, and 23.6%, respectively. Based on the positivity rates of these antibodies, statistically significant differences were observed between male and female participants ($P < 0.01$). Male participants demonstrated positivity rates of 42.48% ($n = 4925$) for Ure, 25.52% ($n = 2959$) for CagA, and 21.63% ($n = 2508$) for VacA. However, females exhibited positive rates of 44.25% ($n = 4945$) for Ure, 29.29% ($n = 3273$) for CagA, and 25.56% ($n = 2856$) for VacA. Furthermore, based on age, statistically significant differences were observed in the positivity rates of Ure, CagA, and VacA antibodies among different age subgroups, namely < 20, 20–30, 30–40, 40–50, 50–60, and 60–75 ($P < 0.001$). A subsequent trend analysis that examined antibody positivity rates and age groups revealed a positive correlation: as age progressed, the positivity rates of Ure, CagA, and

Table 1 Basic characteristics and antibody patterns of the study population

Variable		Total subjects ($n=22769$)	Ure antibody-positive subjects (%)		*P* value	CagA antibody-positive subjects (%)		*P* value	VacA antibody-positive subjects (%)		*P* value
Gender					0.007			0.000			0.000
	Male	1,1594	4,925	42.48%		2,959	25.52%		2,508	21.63%	
	Female	1,1175	4,945	44.25%		3,273	29.29%		2,856	25.56%	
Age group (years)					0.000			0.000			0.000
	0–20	1,390	339	24.39%		186	13.38%		162	11.65%	
	20–30	1,258	469	37.28%		285	22.66%		252	20.03%	
	30–40	2,666	1,150	43.14%		719	26.97%		619	23.22%	
	40–50	3.767	1,734	46.03%		1,073	28.48%		928	24.63%	
	50–60	6,829	3,155	46.20%		2,049	30.00%		1,767	25.87%	
	60–75	6,859	3,023	44.07%		1,920	27.99%		1,636	23.85%	

Table 2 Logistic regression analysis of *H. pylori* ure antibody

Variable		B	Wald	*P*	OR	95% CI	
Gender	Male						
	Female	0.063	5.424	0.020	1.065	1.010	1.122
Age group (years)	0–20						
	20–30	0.609	50.813	0.000	1.839	1.555	2.174
	30–40	0.855	134.743	0.000	2.353	2.036	2.718
	40–50	0.970	189.221	0.000	2.638	2.297	3.029
	50–60	0.975	211.732	0.000	2.652	2.326	3.025
	60–75	0.893	177.464	0.000	2.442	2.142	2.785

Table 3 Logistic regression analysis of *H. pylori* CagA antibody

Variable		B	Wald	*P*	OR	95% CI	
Gender	Male						
	Female	0.181	36.735	0.000	1.199	1.131	1.271
Age group (years)	0–20						
	20–30	0.634	37.358	0.000	1.885	1.538	2.310
	30–40	0.873	93.845	0.000	2.394	2.006	2.856
	40–50	0.941	117.651	0.000	2.561	2.161	3.036
	50–60	1.010	147.665	0.000	2.747	2.334	3.233
	60–75	0.923	122.687	0.000	2.516	2.137	2.962

Table 4 Logistic regression analysis of *H. pylori* VacA antibody

Variable		B	Wald	*P*	OR	95% CI	
Gender	Male						
	Female	0.210	44.586	0.000	1.233	1.160	1.312
Age group (years)	0–20						
	20–30	0.635	33.643	0.000	1.886	1.522	2.337
	30–40	0.831	75.899	0.000	2.296	1.905	2.768
	40–50	0.900	96.054	0.000	2.459	2.054	2.944
	50–60	0.961	119.036	0.000	2.615	2.200	3.108
	60–75	0.864	95.797	0.000	2.374	1.996	2.822

VacA antibodies exhibited a corresponding increase ($P<0.001$). Logistic regression analysis, incorporating age group and gender as variables, revealed that females are at a higher risk of positive antibodies for *H. pylori* Ure, CagA, and VacA than males. Additionally, the positivity rates and associated risks for all three antibodies exhibited an age-dependent increase within the initial five age subgroups. The highest positivity rates (46.20%) and risks were identified in the 50–60 age subgroup (odds ratio [OR] 2.652, 95% confidence interval [CI]: 2.326–3.025) for Ure, 30.00% (OR 2.747, 95% CI: 2.334–3.233) for CagA, and 25.87% (OR 2.615, 95% CI: 2.200–3.108) for VacA. Tables 1, 2, 3 and 4 present the detailed data.

Table 5 Serum typing of *H. Pylori*

Variable		Total subjects	Negative subjects (%)		Type I subjects (%)		Type II subjects (%)		*P*
Gender									0.000
	Male	11594	6529	(56.31%)	2969	(25.6%)	2096	(18.08%)	
	Female	11175	6068	(54.30%)	3286	(29.4%)	1821	(16.30%)	
Age group (years)									0.000
	0–20	1390	1037	(74.60%)	187	(13.5%)	166	(11.94%)	
	20–30	1258	772	(61.37%)	287	(22.8%)	199	(15.82%)	
	30–40	2666	1482	(55.59%)	719	(27.0%)	465	(17.44%)	
	40–50	3767	1987	(52.75%)	1075	(28.5%)	705	(18.72%)	
	50–60	6829	3571	(52.29%)	2056	(30.1%)	1202	(17.60%)	
	60–75	6859	3748	(54.64%)	1931	(28.2%)	1180	(17.20%)	

Table 6 Logistic regression analysis of *H. pylori* serum typing

Serum typing		B	Wald	P OR		95% CI	
Type I							
	Age	0.011	127.829	0.000	1.011	1.009	1.013
	Female						
	Male	−0.173	31.190	0.000	0.841	0.791	0.894
Type II							
	Age	0.007	40.753	0.000	1.007	1.005	1.010
	Female						
	Male	0.068	3.480	0.062	1.071	0.997	1.151

Population distribution analysis of *H. pylori* serotype immunophenotyping

The prevalence of immune type I was 27.5%, while that of immune type II was 17.2%. Based on sex, a significant difference was observed: The male participants exhibited a lower prevalence of immune type I than the female participants [25.6% ($n = 2969$) versus 29.4% ($n = 3286$), $P < 0.001$]. Conversely, the prevalence of immune type II was significantly higher among males than females [18.08% ($n = 2096$) versus 16.30% ($n = 1821$), $P < 0.001$]. Based on age groups (< 20, 20–30, 30–40, 40–50, 50–60, and 60–75), statistically significant differences were observed in the prevalence of immune types I and II ($P < 0.001$). Additionally, a concurrent trend analysis revealed a positive correlation between increased age and the prevalence of both immune types, indicating that the risk of positivity for both types increased with age ($P < 0.001$). Considering that the age grouping data were derived from continuous age measurements, a multivariate logistic regression analysis was performed, incorporating age and gender as variables. The findings revealed that males exhibited a reduced risk of immune type I occurrence than females (OR 0.841, 95% CI: 0.791–0.894). Furthermore, for each additional year in age, the risk of immune type I positivity increases by a factor of 0.011 (OR 1.011, 95% CI: 1.009–1.013) (See Tables 5 and 6).

Distribution of 14C-UBT results within the population

Herein, 19,307 participants were comprehensively screened and divided into two primary groups, positive and negative, based on the results of their 14C-UBT. Notably, 2,891 subjects were identified as belonging to the positive cohort, while 16,416 were designated to the negative cohort, resulting in a positive detection frequency of 14.97%. A univariate analysis was performed based on gender, age, and age group stratifications to attain a more profound understanding. An independent samples t-test was employed for the age analysis, while the chi-square test was used to compare other categorical variables. The statistical analysis revealed significant differences in 14C-UBT outcomes among distinct age groups ($P < 0.001$). Furthermore, a trend analysis examining the relationship between UBT results and age groupings revealed a discernible trend: as age progresses, the probability of a positive 14C-UBT outcome increases ($P < 0.001$). A logistic regression analysis incorporating age data was performed to delve deeper into these observations. The findings revealed the significant effect of age on 14C-UBT results. Specifically, within the 40–60 and 60–75 age ranges, the risk of a positive test result augmented proportionally with advancing age (OR 1.361, 95% CI: 1.252–1.480; OR 1.510, 95% CI: 1.316–1.732) (See Tables 7 and 8).

Table 7 Univariate analysis of variables related to 14C UBT

Variable		Total subjects ($n = 19307$)	Positive subjects	Positive rate (%)	Statistical value	P
Gender					1.167	0.280
	Male	12,377	1879	15.2%		
	Female	6930	1012	14.6%		
Age group					67.431	0.000
	20–40	9689	1251	12.9%		
	40–60	7934	1332	16.8%		
	60–75	1684	308	18.3%		

Table 8 Logistic regression analysis of 14C UBT

Variable		B	Wald	P	OR	95% CI	
Age group	20–40						
	40–60	0.308	52.158	0.000	1.361	1.252	1.480
	60–75	0.412	34.697	0.000	1.510	1.316	1.732

Table 9 Univariate analysis of 14C urea breath and gastroscopy findings among physical examination individuals

Variable	14C-urea negative $n = 190$ (%)	14C-urea positive $n = 103$ (%)	statistical value	P
Gender Male	112 (58.94)	57 (55.33)	0.356	0.621
Female	78 (41.05)	46 (44.66)		
Age (years)	45.042 ± 13.255	45.272 ± 11.921	1.236	0.267
Erosive inflammation	68 (35.78)	48 (46.60)	3.265	0.080
Atrophic gastritis	27 (14.21)	18 (17.47)	0.548	0.499
Ulcer	24 (12.63)	24 (23.30)	5.550	0.021
Duodenal bulb inflammation	49 (25.78)	44 (42.71)	8.835	0.004
Reflux esophagitis	28 (14.73)	26 (25.24)	4.904	0.039

Table 10 Logistic regression analysis of 14C urea breath and gastroscopy findings among physical examination individuals

Variable	B	Wald	P	OR	95% CI
Duodenal bulb inflammation	0.738	7.876	0.005	2.091	1.249 ~ 3.500

Correlation analysis between gastroscopy observations, diagnoses, and 14C-UBT results

Concurrently, 293 participants underwent gastroscopic examination and the 14C-UBT. Depending on the UBT results, these participants were divided into positive and negative groups. Notably, 103 subjects were included in the positive group, while 190 were included in the negative group. A univariate analysis was performed to explore potential associations. This analysis encompassed multiple essential factors, including gender, age, erosive inflammation, atrophic gastritis, ulcerations, duodenal bulb inflammation, and reflux esophagitis. Regarding age, an independent sample t-test was used to evaluate disparities between the two groups. However, chi-square tests were applied to compare the other categorical variables.

The table presented above reveals statistically significant differences in ulcer occurrence (12.63% vs. 23.30%, $P < 0.05$), duodenal bulb inflammation (25.78% vs. 42.71%, $P < 0.01$), and reflux esophagitis (14.73% vs. 25.24%, $P < 0.05$). Factors with $P < 0.1$, erosive inflammation, ulcers, duodenal bulb inflammation, and reflux esophagitis were included in a logistic regression model for further analysis to investigate these associations. Before conducting the logistic regression, a collinearity analysis was performed on the independent variables. The results revealed that the variance inflation factor was < 10 for all variables, indicating no collinearity. This allowed for the inclusion of all variables in the logistic regression model. The subsequent analysis revealed that individuals diagnosed with duodenal bulb inflammation using gastroscopy exhibited an increased risk of testing positive on the 14C-UBT. The OR for this relationship was 2.091, with a 95% CI of 1.249–3.500 (See Tables 9 and 10).

Correlation analysis between gastroscopy manifestations based on the Kyoto classification of gastritis and 14C-UBT results

This study evaluated gastric mucosal inflammation, emphasizing twelve gastroscopy manifestations closely associated with *H. pylori* infection status using the Kyoto Classification of Gastritis as a framework. These manifestations comprise raised erosion, patchy erosion, patchy redness, diffuse redness, mucosal edema, atrophic gastritis, polyps, old hemorrhagic spots, turbid mucus lake, enlarged and snaky rugae, xanthoma, and chicken skin-like alterations (Fig. 2). Statistical analyses revealed significant differences in patchy erosion (31.57% vs. 43.68%, $P < 0.05$), diffuse redness (1.57% vs. 9.70%, $P < 0.01$), mucosal edema (27.89% vs. 54.36%, $P < 0.001$), and hyperplastic polyps (22.63% vs. 12.62%, $P < 0.05$). A collinearity analysis was performed on the independent variables mentioned above to guarantee the reliability of our subsequent logistic regression model, indicating no

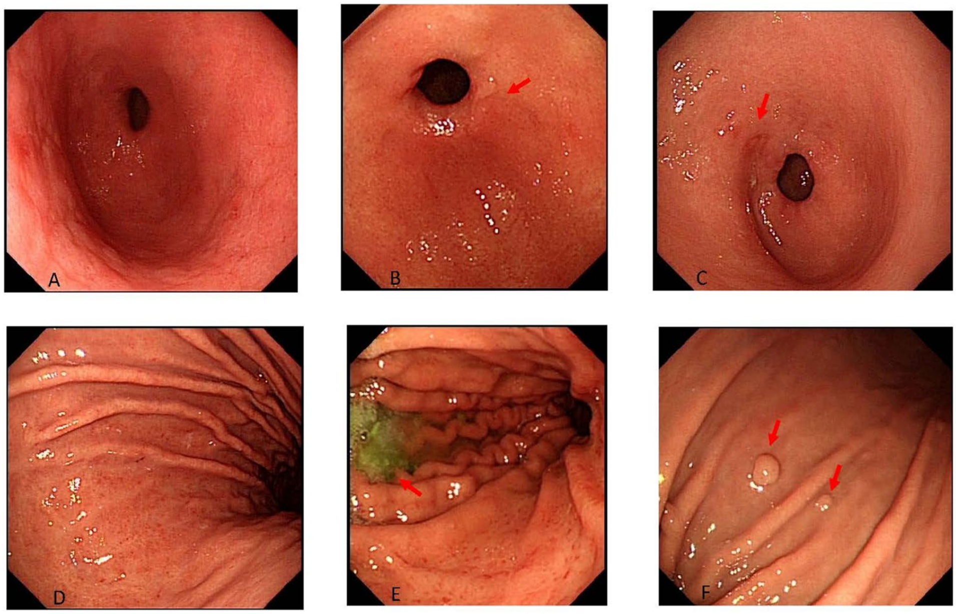

Fig. 2 **A**. Diffuse redness, erosion; **B**, **D**. Dotted Erythema; **C**. Antral erosion; **E**. Mucosal edema, dotted erythema and turbid mucus lake; **F**. Hyperplastic polyps

Table 11 Univariate analysis of lesions observed through 14C-UBT and Kyoto classification of gastritis in physical examination individuals

Variable	14C-urea negative *n* = 190 (%)	14C-urea positive *n* = 103 (%)	χ^2	*P*
Raised erosion	21 (11.05)	12 (11.65)	0.024	0.849
Flaky erosion	60 (31.57)	45 (43.68)	4.260	0.042
Patchy redness	185 (97.36)	98 (95.14)	0.440	0.329
Diffuse redness	3 (1.57)	10 (9.70)	8.582	0.002
Mucosal edema	53 (27.89)	56 (54.36)	20.038	0.000
Atrophic gastritis	26 (13.68)	18 (17.47)	0.752	0.396
Polyp	43 (22.63)	13 (12.62)	4.329	0.043
Old hemorrhagic spot	8 (4.21)	4 (3.88)	0.000	1.000
Turbid mucus lake	10 (5.26)	9 (8.73)	1.330	0.320
Snaky swollen gastric folds	0 (0)	0 (0)		
Xanthoma	0 (0)	0 (0)		
Chicken skin-like change	2 (1.05)	1 (0.97)	0.000	1.000

* If more than 20% of the cells have T < 5, Fisher's exact test will be adopted for analysis

Table 12 Logistic regression analysis of 14C-UBT and Kyoto classification of gastritis in physical examination individuals

Variable	B	Wald	*P*	OR	95% CI
Diffuse redness	1.551	4.772	0.029	4.717	1.173 ~ 18.971
Mucosal edema	0.953	12.933	0.000	2.594	1.543 ~ 4.360
Polyp	–0.727	3.938	0.047	0.483	0.236 ~ 0.991

collinearity among them. Consequently, these four factors were incorporated into a logistic regression model for a more detailed correlation analysis. The results indicated that individuals presenting with diffuse redness and mucosal edema during gastroscopy exhibited an elevated risk of testing positive on the 14C-UBT, with OR of 4.717 (95% CI: 1.173–18.971) and 2.594 (95% CI: 1.543–4.360), respectively. Conversely, individuals with polyps observed under the microscope demonstrated a decreased risk of testing positive, with an OR of 0.483 (95% CI: 0.236–0.991) (See Tables 11 and 12).

Discussion

H. pylori is a Gram-negative, spiral-shaped, microaerobic bacterium that has successfully colonized the gastric mucosa of > 50% of the global population [11, 12]. This bacterium stands out as the only pathogenic microorganism that can survive in the hostile environment of the human gastric mucosa. It has been significantly associated with various gastric pathologies, including atrophic gastritis, gastric ulcers, and gastric cancer. The infection rate varies among different populations and is influenced by diverse factors, including age, gender, racial and genetic predispositions, socioeconomic conditions, geographic location, occupational exposures, lifestyle habits, dietary preferences, and immune status [13–17].

The comprehensive diagnosis of *H. pylori* infection encompasses non-invasive methods, including serology, UBT, fecal antigen tests, and invasive procedures, including endoscopy and biopsy. Serological testing is essential in diagnosis, treatment monitoring, and population-wide screening. It is crucial in public health strategy development, infection control measure implementation, gastric cancer prevention, and scientific research advancement in related fields. Among the pathogenic factors associated with *H. pylori*, urease, VacA, and CagA are particularly noteworthy. Despite over 90% of infected individuals remaining asymptomatic, the bacterium's successful colonization of the gastric mucosa allows it to secrete these toxins. These toxins confer acidic protection by neutralizing gastric acid, forming cellular vacuoles, inducing cellular damage and apoptosis, eventually leading to chronic active inflammation of the gastric epithelium. Studies indicate that while CagA is not present in all strains, its capacity to translocate and integrate into host cells triggers an elevated inflammatory response and cell proliferation [18–20]. Although the VacA gene is prevalent in almost all strains, approximately 50% express the VacA protein. Consequently, antibody screening within vulnerable populations provides valuable insights into the prevalence features of pathogenic strains and aids in assessing virulence levels and drug resistance variations among strains [21–24]. *H. pylori* infection exhibits a significantly high prevalence in East Asia, with seropositive rates of 44.2% in China, 37.6–43.2% in Japan, and 51.0% in Korea [4, 25–27]. A total of 412 eligible studies, comprising 1,377,349 subjects, were included in the analysis, the pooled prevalence of *H. pylori* in mainland China was 44.2% (95% CI: 43.0–45.5%), with an estimated 589 million individuals affected, Guangxi also exhibited a high prevalence rate of 50.7% (95% CI: 43.8–57.55%) [25]. In our study conducted in Wuzhou City, Guangxi Province, the seropositivity rates for Ure was 43.3%, respectively, suggesting a high prevalence of *H. pylori* infection in the studied region.

Immune Type I *H. pylori*, characterized by its production of VacA and CagA, demonstrates higher infectivity and pathogenicity than immune type II *H. pylori*, which only produces Ure and does not produce cytotoxins [24, 28–31]. Our study demonstrated that the overall seropositive rate for immune type I *H. pylori* in the general population is 27.5%, whereas the seropositive rate for immune type II is 17.2%. Among those infected with *H. pylori*, 61.52% are infected with type I *H. pylori*, compared to 38.48% infected with type II. This finding indicates that most *H. pylori* infections in our studied region are primarily attributed to the more contagious type I strain. *H. pylori* type I is characterized by the expression of virulence factors such as CagA and/or VacA, exhibiting high toxicity and a strong association with diseases such as peptic ulceration and gastric cancer. In contrast, *H. pylori* type II demonstrates little or no expression of these virulence factors, resulting in reduced toxicity and pathogenicity, often causing only mild or no symptoms. Due to its heightened toxicity and pathogenicity, *H. pylori* type I typically necessitates aggressive eradication therapy. Treatment regimens may involve combination antibiotic therapies to enhance eradication rates. At the public health level, heightened surveillance and control measures for *H. pylori* type I are crucial for the prevention of severe diseases, such as gastric cancer. For patients infected with *H. pylori* type II who are asymptomatic or exhibit only mild symptoms, and where gastroscopy and pathological assessment do not reveal significant gastric mucosal damage, clinicians may adopt a "watch-and-wait" or "symptom management" approach. However, this management of "asymptomatic infected individuals" or "patients with dyspepsia" also implies a potential for increased disease underdiagnosis.

The impact of gender on *H. pylori* infection rates is controversial in this study. While some studies reported no significant gender-based disparities in the risk of *H. pylori* infection, our research indicates higher seropositive rates for Ure, CagA, and VacA antibodies among females than among males. Multiple international studies have demonstrated a higher prevalence of *H. pylori* infection in rural settings, particularly among children and females [32–38]. In northern Sudan, for instance, asymptomatic female adolescent students exhibit a significantly elevated risk of infection compared to their male counterparts (adjusted odds ratio of 3.04) [39]. This phenomenon can be attributed to the specific socioeconomic conditions in underdeveloped regions, encompassing poor hygienic practices and low socioeconomic status, which are pivotal factors influencing *H. pylori* infection rates [40]. Within these contexts, females and children are more susceptible to social discrimination and marginalization, leading to unequal access to healthcare and subsequently increasing their vulnerability to infectious diseases and malnutrition. Furthermore, research has revealed that females also experience a significantly higher risk of poor symptom improvement and eradication failure following *H. pylori* treatment [36, 38, 41–44]. This disparity may be associated with multiple factors, including hormonal levels, anxiety states, visceral hypersensitivity, as well as alterations in gut microbiota, mucosal integrity, and immune function. It is noteworthy that our study observed a relatively higher seropositivity rate for antibodies among females, however, this finding is not contradictory to the observation that there was no significant gender difference in the positive results of the 14C-UBT test. Serological antibody testing positivity reflects both "current infection" and "past infection," and IgG antibodies may persist even after successful eradication therapy, thus accounting for the gender-based differences in antibody positivity rates.

The infection rate of *H. pylori* progressively increases with age, reaching a peak within the 50–60 age bracket. Our findings are consistent with those of existing data, suggesting that advancing age is associated with an increased cumulative risk of *H. pylori* infection. This trend is primarily attributed to the increasing number of potential exposure windows to infection sources as individuals age. Established risk factors for *H. pylori* infection include smoking, alcohol consumption, unhealthy eating habits, and frequent social gatherings. Additionally, as individuals age, they may be prone to developing other chronic illnesses, and their immune system gradually declines, thereby reducing resistance to *H. pylori* infection and increasing susceptibility.

Serological testing, known for its simplicity and wide applicability, is commonly used in epidemiological surveys. However, it has limitations in reflecting active infections, as a positive serum antibody test can only suggest an active infection in cases where the individual has not undergone eradication therapy. Conversely, the UBT emerges as a non-invasive and highly effective method for detecting *H. pylori* infection. It is characterized by its high precision, strong specificity, rapid results, and user-friendliness. Thus, various guidelines recommend UBT as the preferred method for diagnosing active *H. pylori* infections and for post-eradication therapy follow-up. According to China's Primary Care Guidelines for *H. pylori* Infection (Practical Edition 2019), a positive UBT result indicates an active infection [45–47].

In our hospital, we administered the 14C-UBT to 19,307 individuals, which yielded a positivity rate of 14.97%. The positivity rate of the 14C-UBT increases progressively with age, peaking in the 60–75 age subgroup. This age distribution mirrors that observed in serological tests for *H. pylori*. The prevalence of *H. pylori* detected through this method is relatively low and is significantly affected by previous medical treatments for *H. pylori*. The study analyzed the global trend of *H. pylori* prevalence from 1980 to 2022 using PubMed, Embase, MEDLINE, Scopus, and Web of Science. It found higher infection rates in studies using serological methods (53.2%) compared to non-serological ones (41.1%), consistent with our findings [48]. Furthermore, the recent administration of antibiotics and proton pump inhibitors may result in false-negative outcomes. Therefore, it is imperative to implement standardized operational procedures, utilize high-quality reagents, mitigate interfering factors, ensure precise sample collection, and provide comprehensive technical training, in order to enhance the diagnostic accuracy of UBT [26, 49–57]. Histological confirmation through biopsy remains the gold standard for diagnosing *H. pylori* infection [58, 59]. Nevertheless, emerging evidence suggests that, in certain situations, the meticulous observation of mucosal characteristics via optical endoscopy can significantly reduce the need for unnecessary biopsies. Japanese scholars have presented the Kyoto gastritis consensus report, which outlines the various gastric mucosal manifestations associated with *H. pylori* infection status during endoscopic examination [60]. Indicators of active infection include diffuse redness, mucosal swelling, atrophy, intestinal metaplasia, hyperplastic polyps, xanthoma, enlarged or sinuous folds, turbid mucus, and chicken skin-like mucosal changes [4, 61–68].

Our analysis of individuals who underwent endoscopy and the 14C-UBT revealed an elevated detection rate of ulcers, duodenal bulb inflammation, and reflux esophagitis in the group that tested positive on the UBT. Regression model analysis revealed an increased risk of a positive breath test result among individuals diagnosed with duodenal bulb inflammation [69]. Additionally, we examined the relationship between endoscopic findings, based on the principles outlined in the simplified Kyoto gastritis classification, and the breath test results. The group that tested positive on the UBT demonstrated higher detection rates of patchy erosion, diffuse redness, and mucosal edema but a lower detection rate of hyperplastic polyps. Similarly, regression model analysis revealed an increased risk of a positive test result in subjects exhibiting diffuse redness and mucosal edema, while the risk was reduced in those presenting with polyps.

The relationship between polyps and *H. pylori* infection is controversial. Although polyps carry a small but significant risk of malignant transformation, large-scale cohort studies suggest a negative correlation between the presence of the pathogen and the occurrence of polyps, which is consistent with our findings. This correlation may be influenced by various factors, including the size of the epidemiological survey population, the duration of *H. pylori* infection, complex factors related to polyp resorption, history of eradication therapy, long-term use of proton pump inhibitors, and internal dysbiosis. However, further research is needed to elucidate the risk factors and mechanisms associated with this apparent protective effect [70, 71]. Herein, we assessed the correlation between abnormal endoscopic observations, lesion locations, and their corresponding pathological outcomes with *H. pylori* infection among individuals. Our results indicate that abnormal upper gastrointestinal endoscopy findings are common in this population, with chronic gastritis being the most prevalent condition. Specifically, duodenal bulb inflammation, diffuse redness of the gastric mucosa, and mucosal edema revealed a positive association with current *H. pylori* infection.

The early identification of high-risk cohorts based on routine physical examination and the detection of abnormal endoscopic findings can facilitate the prompt implementation of preventive measures or treatments. This proactive approach allows for prompt diagnosis and intervention, effectively halting the progression of gastrointestinal disorders. Given the covert nature of chronic infections caused by this pathogen, there is a growing consensus advocating for the screening and management of "healthy subjects," "asymptomatic populations," and individuals diagnosed with "chronic gastritis," regardless of the presence of dyspepsia symptoms. These cohorts should be the primary focus of early screening efforts, with targeted monitoring and diagnostic strategies.

The rapid advancement of artificial intelligence (AI) technology has unveiled its considerable potential in the diagnosis and management of *H. pylori* infection. Utilizing convolutional neural network (CNN) technology, these AI systems excel in image recognition tasks, enabling the precise identification of abnormalities within endoscopic images. Specifically, the systems can detect gastric mucosal changes induced by *H. pylori* infection and compare them with normal mucosal patterns. Furthermore, AI algorithms are capable of automatically segmenting distinct regions within the endoscopic images, allowing for the extraction of pivotal information that enhances diagnostic efficiency and accuracy [72–77]. Notably, the diagnostic accuracy of these AI systems is on par with that of experienced physicians. The advantages of AI become particularly evident when juxtaposed with the performance of less experienced practitioners, highlighting the potential of AI to bridge gaps in diagnostic proficiency. The incorporation of AI technology into the diagnostic process for *H. pylori* infection is gradually reshaping traditional paradigms, leading to improvements in both the accuracy and efficiency of *H. pylori* diagnosis.

This study acknowledges several limitations. Primarily, being a retrospective analysis, it is inherently prone to case selection bias and potential information loss, as the dataset relies on previously recorded information, over which the investigators had no control concerning the data acquisition process or its precision. Secondly, the study's single-center design, conducted exclusively in Wuzhou, China, restricts the generalizability of the results, which may be specific to the demographic characteristics of that region and may not exhibit broad external validity. Despite the inclusion of a substantial sample size, inadequate representation of certain subgroups, such as males or elderly individuals, within the cohort could potentially compromise the widespread applicability of the findings. Furthermore, uncontrolled confounding variables, including dietary patterns, lifestyle factors, and genetic predispositions, may introduce biases that could affect the interpretation of the results. To address these limitations, we advocate for the conduct of future multicenter, prospective studies to validate the present findings and underscore the significance of such methodological rigor in enhancing the reliability and generalizability of research outcomes.

Conclusion and recommendations

The recent expert consensus in China underscores infection as the primary controllable risk factor for gastric cancer. Carrying out population surveys on *H. pylori* infection is essential for understanding the epidemiological characteristics of this pathogen, consistent with current scientific research requirements in pathogen epidemiology. Our investigation demonstrated that the prevalent *H. pylori* strain in this region is primarily of the pathogenic type I, and asymptomatic individuals are at increased risk of active infection. These fundamental data provide a scientific basis for the rational allocation of medical resources, efficient disease management, and shaping public health policies. By integrating advanced technologies, including deep learning, artificial intelligence algorithms, convolutional neural networks, and gastrointestinal endoscopy image analysis, we can enhance decision-making processes in diagnostic tests for *H. pylori* infection. This integration enables accurate differentiation between active infections, previous infections, and non-infected states. Therefore, it fosters a deeper understanding of the pathogenesis triggered by *H. pylori*, identifies populations prone to more severe and concealed diseases, and assists in addressing this significant health challenge and formulating novel infection management strategies.

Abbreviations

H. pylori	Helicobacter pylori
Ure	Urease
CagA	Cytotoxin associated gene A
VacA	Vacuolating cytotoxin A
14C-UBT	14C-urea breath test
OR	Odds Ratio
CI	Confidence Interval

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Author contributions
L.Y. and Q.H. were involved in the development of proposal and study design and manuscript preparation. S.L. and X.P. were involved in data collection, processing and analysis. M.S. and S.Z. were involved in the preparation of study design and data collection. J.Y. and D.H., main author of the study, involved in proposal writing, study design, data collection, data processing and analysis, and preparation of the manuscript. All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All participants were fully informed and provided written consent prior to their involvement in this study. The research was conducted in compliance with the ethical guidelines established by the Institutional Medical Ethics Review Board of Wuzhou Red Cross Hospital, Guangxi, People's Republic of China (LL2022-76).

Competing interests

The authors declare no competing interests.

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