



Detection of virulence gene belonging to *cag* pathogenicity island in *Helicobacter pylori* isolates after multiple unsuccessful eradication therapy in Northwest Croatia

DIJANA VARDA BRKIĆ¹
MIROSLAVA KATIČIĆ^{2,3}
BRANKA BEDIĆ^{1,3}
ALEKSANDRA PRESEČKI STANKO¹
VANDA PLEČKO^{1,3}

¹ Department of Clinical and Molecular Microbiology, University Hospital Centre Zagreb, Kišpatićeva 12, Zagreb

² University Hospital Merkur, Zajčeva 19, Zagreb

³ School of Medicine, University of Zagreb, Zagreb, Croatia

Correspondence:

Dijana Varda Brkić
dijanavb098@gmail.com

Key words: *Helicobacter pylori*, genotyping, *cag* pathogenicity island, *cagA*

Abstract

Background: Some of the genes belonging to *cag* pathogenicity island (*cagPAI*) in *Helicobacter pylori* were found to be associated with an increased severity of gastric mucosal inflammation that might lead to the development of gastroduodenal disease.

Aim: The aim of our study was to define a group of patients based on the frequency of virulence genes of *cagPAI* island and comparison with pathohistological alterations of gastric mucosa who need to be subjected to further eradication therapy after previous unsuccessful eradication therapy and in spite of benign endoscopic findings.

Material and methods: In total 103 *H. pylori* isolates were analysed. Genes encoding virulence factors were detected by PCR with primers for 10 loci in *cagPAI*: *Apcag* (*cagA* promotor region), *cagA1*, *cagA2*, *cagA3*, *cagM*, *cagT*, *cagE*, *LEC*, *tnpA* and *tnpB*. The patients who provided isolates were classified into three clinical categories: non-ulcer dyspepsia ($n=69$), erosio/ulcus ventriculi ($n=22$) and erosio/ulcus duodeni ($n=12$).

Results: 16 strains (15.5%) were negative for all tested genes. 87 (84.5%) of the isolates had partially deleted *cagPAI*. None of the isolates possessed all 10 genes. The frequency of single *cagPAI* genes were as follows: *Apcag* 63.1%, *cagA1* 71.8%, *cagA2* 69.9%, *cagA3* 5.8%, *cagM* 71.8%, *cagE* 75.7%, *cagT* 68%, *tnpA* 9.7%, *tnpB* 7.8% i *LEC* 48.5%.

No statistically significant difference was observed between the presence of any *cagPAI* genes and endoscopic diagnosis ($p>0.16$). The presence of *CagA2*, *Apcag* and *cagM* showed statistically significant correlation with higher level of patohistological parameters of gastritis ($p<0.05$).

Conclusions: *H. pylori* isolates with positive *cagA*, *Apcag* and *cagM* genes are correlated to higher degree of patohistological lesions of gastric mucosa; without statistically significant correlation with endoscopic diagnosis.

INTRODUCTION

Many studies have confirmed the role of *H. pylori* in the development of chronic gastritis, gastric and duodenal ulcer and the ethiological role in the pathogenesis of gastric carcinoma and mucosa-associated lymphoid tissue (MALT) lymphoma.

H. pylori possess many virulence genes; one of them is *cag* pathogenicity island (*cagPAI*) (1). *CagPAI* is since its discovery the most analysed

Received July 12, 2015.
Revised February 19, 2016.
Accepted February 22, 2016.

segment of *H. pylori* genome. It is approximately 40 kilobase pairs region of *H. pylori* chromosome and contains around 30 genes divided into region I and II. *CagPAI* is defined as intact if all genes are present, partially deleted as presence of several genes and negative (deleted) if there are no genes at all (2). Many studies report correlation between presence of intact *cagPAI*, partially deleted and deleted *cagPAI* and clinical outcome. Some authors correlate intact *cagPAI* with severe gastroduodenal diseases, with higher grade of chronic gastritis and premalignant lesions of gastric mucosa (1, 3–4), while partially deleted and deleted *cagPAI* are associated with milder forms of gastroduodenal disease and lower grade of pathological alternations of gastric mucosa (5–6). On the contrary, some of the authors did not find correlation between *cagPAI* and gastroduodenal disease (7). *CagPAI* encodes multiple structural components of bacterial type IV secretion system (T4SS). T4SS translocates *cagA* protein directly to the cytosol of the gastric epithelium where it gets tyrosin phosphorylated by Src-family kinases and becomes able to alter the host cell functions leading to malignant transformation (2).

CagA gene is located in the region I of *cagPAI* and is considered to be the marker of this region. *CagA* positive isolates are associated with more severe clinical features in many studies. However, there are contradictory results in the references regarding these studies.

CagE is also located in the region I and is necessary to induce production of interleukin IL-8. Some authors consider *cagE* gene to be better marker of *cagPAI* region compared to *cagA* and more useful in monitoring the progress of *H. pylori* induced gastric disease. *CagT* gene is a marker of *cagII* region and some studies connect it with more severe clinical disease (8). *LEC* (left terminal end of *cagII*) is not necessary for translocation of *cagA* into the host cell or induction of interleukin IL8. It is associated with peptic ulcer and adenocarcinoma. Some of the study found connection of *tnpA* gene with peptic ulcer (9).

There are no published studies on the presence of *H. pylori* virulence genes in Croatia. Considering quite large number of patients with multiple unsuccessful eradication therapy, in spite of lack of clinical symptoms and benign endoscopic result, there is a question to pose whether to insist on eradication or not.

The aim of our study was to detect virulence genes of *H. pylori* just in these patients as a possible predictors of future severe gastroduodenal diseases, by comparing it with clinical and pathohistological results.

MATERIAL AND METHODS

Patients

The study analysed gastroscopic test results and biptic specimens of gastric mucosa with positive *H. pylori* culture in 103 patients examined during routine, clinical gastro-

duodenoscopies in the endoscopic laboratory of the University Hospita Merkur in Zagreb during the period 2008.–2012. Microbiological and molecular analysis was performed at the Department for Clinical and Molecular Microbiology of the University Hospital Center in Zagreb and pathohistological testing of the gastric biopsy specimens at the Department for Pathology of University Hospital Merkur. The study was approved by the Ethical Committee of the University Hospital Center Zagreb and University Hospital Merkur. The patients had signed the informed consent. Twenty-six men and seventy-seven woman in the age range of 28 to 80 years were included in the study. All patients were previously treated with eradication therapy for *H. pylori*. According to the endoscopic finding patients were classified in three groups: non ulcer dyspepsia (NUD), erosio/ulcus ventriculi (EUV), erosio/ulcus duodeni (EUD).

Bacterial culture

The biopsy specimens (one from corpus and one from antrum) were transported in tioglicolate broth, homogenized and seeded on Columbia agar with addition of 7% horse blood and *Helicobacter pylori* Selective Supplement SR 0147E (Oxoid) for cultivation of *H. pylori*. The plates were incubated in microaerophilic atmosphere with 100% humidity for 3–5 days. Identification was done based on macromorphology, micromorphology and biochemical testing (oxidase, urease, catalase). The strains were stored at –80°C in brucela broth with 10% glycerol.

DNA extraction

Extraction of chromosomal DNA was performed with commercial kit: High Pure PCR Template Preparation Kit, Version 16 (Roche Diagnostics GmbH, Mannheim, Germany) according to the manufacturer's recommendation. The DNA was stored at –20°C until used for molecular studies.

PCR amplification

PCR was used to detect the following genes: *cagA1*, *cagA2*, *cagA3*, *cagE*, *cagM*, *cagT*, *cagA* promotor region (*Ap-cag*), *tnpA*, *tnpB* and *LEC* using primers and conditions shown in Table 1. (10–14). A set of primers P1 and P2 that amplified a 26 kDa antigen (*Ag*) gene present in all strains of *H. pylori* was used as a positive PCR control. All PCR reactions were performed using a GeneAmpC PCR System 9700 (A6B Applied Biosystems). PCR products were visualised by electrophoresis in 2% agarose gel, after staining with ethidium bromide and examined in UV transilluminator. A 100 bp DNA ladder (Sigma) was used as a size marker. Reference strains 47164 and 17874 (Culture collection, University of Goethenburg) were used a positive control.

Histology

Specimens for pathohistological analysis were fixed in a standard 4% neutral buffered formalin, and cut into

Table 1. Primers used in this study

Gene	Primer	Primer sequence	Amplicon size	Annealing temp.	Reference
<i>cagM</i>	Cag 5	ACAAATACAAAAAGAAAAAGAGGC	586 bp	53 °C	10
	Cag 6	ATTTTTCAACAAGTTAGAAAAAGCC			
<i>tnpA</i>	Cag10	ATCAGTCCAAAAAGTTTTTCTTTCC	344 bp	53 °C	10
	Cag11	TAAGGGGGTATATTTCAACCAACCG			
<i>tnpB</i>	Cag 8	ACAAATACAAAAAGAAAAAGAGGC	569 bp	53 °C	10
	Cag 9	AGCTAGGGAAAAATCTGTCTATGCC			
<i>cagA2</i>	CAG1	AGACAACCTTGAGCGAGAAAG	320 bp	53 °C	11
	CAG-2	TATTGGGATTCTTGGAGGCG			
<i>cagE</i>	CagE-F1	ACAAATACAAAAAGAAAAAGAGGC	329 bp	52 °C	12
	CagE-R1	GAAGTGGTTAAAAAATCAATGCCCC			
<i>cagT</i>	CagT-F1	CCATGTTTATACGCCTGTGT	301bp	52 °C	12
	CagT-R1	CATCACCACACCCTTTTGAT			
<i>cagA3</i>	CagA-F1	AACAGGACAAGTAGCTAGCC	701 bp	52 °C	12
	CagA-R1	TATTAATGCGTGTGTGGCTG			
<i>cagA1</i>	CagA-F2	ACAAATACAAAAAGAAAAAGAGGC	349 bp	52 °C	12
	CagA-R2	CTGCAAAAGATTGTTTGGCAGA			
<i>Apcag</i>	CagA-R2	CTGCAAAAGATTGTTTGGCAGA	730 bp	52 °C	12
	AP-F1	GTGGGTAAAAATGTGAATCG			
<i>LEC</i>	LEC-F1	ACATTTTGGCTAAATAAACGCTG	320-550 bp	55 °C	13
	LEC-R1	TCTCCATGTTGCCATTATGCT			
<i>Ag</i>	P1	TGGCGTGTCTATTGACAGCGAGC	298 bp	57 °C	14
	P2	CGTGCTGGGCATACTTCACCATG			

slides. Slides were routinely stained and analysed according to modified Sydney classification of gastritis (15). Metaplasiae were scored as yes or no, concerning that none of the patients had incomplete metaplasia of II or III grade. All metaplasias were of the I grade.

Statistical analysis

Age and complex scores were expressed as mean and standard deviation (SD). Comparison for complex scores were done using Student's t-test. Categorical variables were presented as frequencies (%). The comparison between subgroups for categorical variables were done using χ test or Fischer exact test with the calculation of odds ratio (OR) together with 95% confidence intervals (CI). Logistic regression analysis was used to calculate OR (95% CIs) for the association of the presence of individual genes with complex scores (OR was calculated for the 1-point change in complex score). A P value of <0.05 was considered statistically significant for all tests performed. The analysis was performed using STATISTICA, version 10. (StatSoft, Inc., OK, USA).

RESULTS

In the study were included 103 patients: 25 men and 78 woman in the age range of 28 to 81 years, with median age of 55.8 years (SD±11.8). According to endoscopic results patients were classified into three groups: 68 (66%) with non-ulcer dyspepsia (NUD), 22 (21.4%) with erosio/ulcus ventriculi (EUV), and 13 (12.6%) with erosio/ulcus duodeni (EUD).

Out of 103 *H. pylori* isolates 16 (15.5%) had deleted *cagPAI*, and 87 (84.5%) partially deleted *cagPAI*. None of the isolates had intact *cagPAI*. There was no statistically significant difference in the distribution of *cagPAI* either according to the gender ($\chi^2=0.005$, $df=1$, $p=0.941$) or according to the endoscopic diagnosis ($\chi^2=1.142$, $df=2$, $p=0.565$) as shown in Table 2.

The frequency of particular genes was as follows: *cagA1* 71.8%, *cagA2* 69.9%, *cagA3* 5.8%, *cagE* 75.7%, *cagM* 71.8%, *tnpA* 9.7%, *cagT* 68%, *Apcag* 63.1%, *LEC* 48.5% and *tnpB* 7.8% as shown in Figure 1.

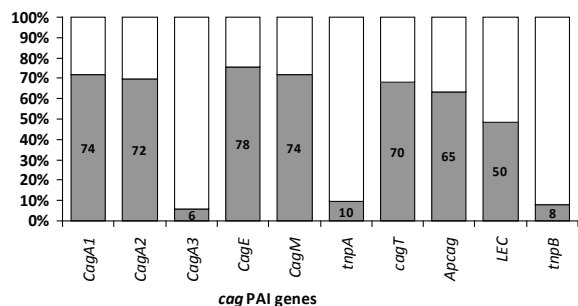


Figure 1. Percentage and number of positive cagPAI genes from *H. pylori* isolates (N=103)

Table 2. Correlation of cagPAI and endoscopic diagnosis

Endoscopic diagnosis	Partially deleted cagPAI	Completely deleted cagPAI
EUV 22 (21.4%)	17 (77.3%)	5 (22.7%)
EUD 13 (12.6%)	11 (84.6%)	2 (15.4%)
NUD 68 (66.0%)	59 (86.8%)	9 (13.2%)

EUV – erosio/ulcus ventriculi; EUD – erosio/ulcus duodeni; NUD – non-ulcer dyspepsia.

Pathohistological analysis of antrum revealed inflammation in all patients (100%), activity was found in 66% of the patients, atrophy in 6.8% and intestinal metaplasia in 24.3%. All patients had inflammation in the corpus. Activity was found in 62.2% of the patients. Atrophy was present in 4.9% and metaplasia in 13.6% of the patients. Table 3. shows the distribution of different grades of pathohistological parameters of gastritis in the antrum and corpus.

There was no statistically significant difference in pathohistological lesions between the patients with partially deleted cagPAI and those with deleted cagPAI (p>0.05 for all parameters describing pathohistological lesions).

The presence of CagA2 was significantly related to the higher grade of inflammation of antrum ($\chi^2=6.872$, df=2, p=0.032), with increased density of *H. pylori* in the corpus ($\chi^2=16.7$, df=3, p=0.001), and with higher total score for the corpus (mean±SD=4.1±1.5 for CagA2+, 3.3±1.4 for CagA2-, t=2.687, p=0.008) as shown in Table 4.

The presence of Apcag was significantly correlated with higher inflammatory score of antrum (Apcag+: mean±SD=4.9±1.7; Apcag-: 4.0±1.7; t=2.332, p=0.022) (Table 4).

The presence of cagM was related to the higher density of *H. pylori* in the corpus ($\chi^2=9.864$, df=3, p=0.020). and higher total score for the corpus (CagM+: mean±SD=4.1±1.6; CagM-: 3.4±1.4; t=2.021, p=0.046) (Table 4).

Table 3. Pathohistological characteristics of the patients (n=103)*

Characteristics	Positivity	Score	No (%)	Mean (SD)	
Antrum	Activity	0	35 (34.0)		
	PMN	68 (66%)	1 50 (48.5) 2 15 (14.6) 3 3 (2.9)		
	Inflammation	103 (100%)	1 35 (34.0) 2 65 (63.1) 3 3 (2.9)		
	Inflammatory score			2.5 (1.1)	
	Atrophy	7 (6.8%)	0 96 (93.2) 1 7 (6.8)		
	Metaplasia	25 (24.3%)	0 78 (75.7) 1 25 (24.3)		
	<i>H. pylori</i>	92 (89,3%)	0 11 (10.7) 1 33 (32.0) 2 34 (33.0) 3 25 (24.3)		
	Total score			4.5 (1.8)	
	Corpus	Activity	64 (62.2%)	0 39 (37.9) 1 53 (51.5) 2 11 (10.7)	
		PMN	103 (100%)	1 55 (53.4) 2 43 (41.7) 3 5 (4.9)	
Inflammation		103 (100%)	1 55 (53.4) 2 43 (41.7) 3 5 (4.9)		
Inflammatory score				2.2 (1.0)	
Atrophy		5 (4,9%)	0 98 (95.1) 1 4 (3.9) 2 1 (1.0)		
Metaplasia		14 (13,6%)	0 89 (86.4) 1 14 (13.6)		
<i>H. pylori</i>		99 (96,1%)	0 4 (3.9) 1 61 (59.2) 2 25 (24.3) 3 13 (12.6)		
Total score				3.8 (1.5)	
Total score antrum+corpus				8.4 (2.5)	

*According to the Updated Sydney system classification with metaplasia absent=0 and present=1, PMN= Polymorph-nuclear cells

The presence of cagT and LEC was related to less frequency of antrum atrophy (cagT, $\chi^2=5.35$, df=1, p=0.021).

Correlation between any of ten cagPAI genes and endoscopic diagnosis (p>0.16 for all) was not found in this study.

DISCUSSION

In our study, we amplified 10 *H. pylori* genes in order to characterize cagPAI. Intact cagPAI was not found but there was 84.5% partially deleted, and 15.5% completely

Table 4. Association of *H. pylori* *cagPAI* genes with pathohistological changes of gastric mucosa

Pathohistology	Grade	Negative	Positive	Statistics	P-value	OR (95% CI)
<i>cagA2</i>						
Inflammation, antrum	1	16	19	$\chi^2=6.872$	0.032	2.941 (1.216–7.217) for grade 1 vs. 2/3
	2	15	50			
	3	0	3			
<i>H. pylori</i> , corpus	0	3	1	$\chi^2=16.700$	0.001	15.02 (4.558–67.12) for grade 0/1 vs. 2/3
	1	25	36			
	2	1	24			
Total score, corpus	3	2	11	$t=2.687$	0.008	3.841 (1.531–9.638)
	Mean±SD	3.3±1.4	4.1±1.5			
<i>CagM</i>						
<i>H. pylori</i> , corpus	0	1	3	$\chi^2=9.864$	0.020	8.665 (2.621–38.73) for grade 0/1 vs. 2/3
	1	24	37			
	2	2	23			
	3	2	11			
Total score, corpus	Mean±SD	3.4±1.4	4.1±1.6	$t=2.021$	0.046	3.259 (1.293–8.215)
<i>cagT</i>						
Atrophy, antrum	0	28	68	$\chi^2=5.352$	0.021	0.165 (0.030–0.918)
	1	5	2			
<i>Apcag</i>						
Inflammatory score, antrum	Mean±SD	2.2±1.0	2.7±1.1	$t=2.283$	0.025	2.448 (1.285–26.008)
Total score, antrum	Mean±SD	4.0±1.7	4.9±1.7	$t=2.332$	0.022	2.349 (1.027–5.374)
<i>LEC</i>						
Atrophy, antrum	0	46	50		0.016*	0 (0–0.524)
	1	7	0			

deleted. In contrast, in the study done in Mexico which included 11 genes, there was 90% of intact *cagPAI*, 4% of partially deleted and 6% of completely deleted (16).

We want to emphasise that there is discordance between different studies in the number of *cagPAI* genes analysed, and the definition of intact, deleted and partially deleted *cagPAI*. Most studies analysed limited number of genes. Salih et al. analyzed 4 genes of *cagPAI* and reported 42.1% of intact, 39.5% of partially deleted and 18.4% completely deleted *cagPAI* and the correlation of intact *cagPAI* and duodenal ulcer (17). Baghaei et al. analyzed three genes and reported 17% of intact *cagPAI*, 62% of partially deleted and 20% of completely deleted in Iran population (8). Nygen et al. analysed 30 genes with the same number of strains and similar endoscopic diagnosis as in our study and found 88% of intact, and 12% of partially deleted in Vietnam population (18). Based on bibliographical data it is evident that the frequency of intact *cagPAI* varies depending on the geographic area.

Results of our study did not demonstrate any correlation between deleted and partially deleted *cagPAI* and either endoscopic diagnosis or pathohistological lesions. It is hard to explain whether our results reflect the situation in our geographic region or if they are related to a specific category of patients with predominant non-ulcer

dyspepsia. The study from Maeda et al. from Japan confirmed our observation that partially deleted *cagPAI* is associated with non-ulcer dyspepsia in contrast with intact *cagPAI* found in patients with gastric cancer (19). We do not have the data for different categories of patients with other grades of gastroduodenal disease. This is the first study of genotyping of *cagPAI* in Croatia. The future studies should be focused on genotyping of *cagPAI* in Croatian patients with severe gastroduodenal disease.

CagA is considered to be a marker of *cagPAI* region (20). In our study we analysed three different segment of *cagA* gene. *cagA1* segment close to the promoter region, middle segment *cagA2* and right end *cagA3*. While the rate of *cagA1* and *cagA2* positivity was similar (71.8%) and (69.9%) respectively, the frequency of *cagA3* was low (5.8%). The frequent deletion of *cagA3* compared to *cagA1* and *cagA2* in the control strains reported by Matar et al. was attributed to decreases pathogenicity (9). Prevalence of *cagA* positive strains differs between the countries and is the highest in East Asia (90%), Japan (100%) (21) and Bulgaria (84.9%) (22). The moderate prevalence was found in Iran (62%) (23), Slovenia (61%) (24), Columbia (64%) (21), Turkey (49%) (25), Equador (46%) (26) and Portugal (31.8%) (27). The previous studies on *H. pylori* in Croatia reported the prevalence of serum antibodies

against bacterial virulence antigens p120 (CagA- cytotoxin associated antigen) of 91.3% in the group of patients with severe gastroduodenal diseases (28). In our study the prevalence of *cagA* was not statistically significantly correlated with clinical diagnosis which is in concordance with the study of Strauss *et al.* (81% positive) (29) but different from the study of Marie M *et al.* (62% positive) where the presence of *cagA* was correlated with gastritis and peptic ulcer (30). In our study the presence of *cagA* was correlated with higher degree of inflammation in the gastric mucosa, particularly in antrum ($p=0.001$). In the previous study from Croatia p120 (*cagA*) seropositivity was significantly more often present in patients with higher activity grade in the antrum (28). These results are in concordance with other studies which proved that *cagA* enhances accumulation of neutrophils, determined as inflammatory score and according to some studies induces the production of interleukine IL-8 (17). These results are confirmed by studies from Iran (31). No correlation between *cagA* and *cagE* and clinical outcome in Iran patients was found (32). In our study *cagA2* is related to the higher density of *H. pylori* ($p=0.001$) and this correlation was confirmed by other authors (33–35). However, some studies did not find any significant relationship between *cagA* positivity and *H. pylori* density, neutrophil activity, lymphoid aggregation in lamina propria and glandular atrophy in the biopsies, but significant association was detected with severe chronic gastritis (23). The frequency of *cagE* in our study was higher than of *cagA* (75.7% vs 71.8%). This is in agreement with some studies which consider *cagE* to be a better marker of *cagI* region than *cagA* (9, 36). We did not find any association between *cagE* and endoscopic diagnosis and pathohistological lesions which is in agreement with the results from a study conducted in Portugal where *cagE* is more prevalent than *cagA* (27). Modena *et al.* have not found association between *cagE* and clinical outcome (37), contrarily to the studies which described higher frequency of *cagE* and severe gastroduodenal disease such as ulcer and gastric cancer, than in gastritis (3). *CagT* as a marker of *cagII* region was identified in 68% of our isolates and was associated with decreased frequency of antrum atrophy without any correlation with clinical diagnosis. However, some authors did not report correlation with either clinical diagnosis or pathohistological alterations of gastric mucosa (8). Mattar *et al.* reported that 98% of the patients with ulcer disease retained *cagT* gene (9), while the isolates with deleted *cagT* were more frequent in the patients with chronic gastritis compared with peptic ulcer disease or gastric cancer in Japanese population (12). Fisher *et al.* claim that the patients with *H. pylori* lacking *cagT* have dysfunctional T4SS and are unable to translocate *cagA* protein into the host cell (38). In the study from England the majority of ulcer disease strains retained the *cagT* and *cagE* gene (39). In our study *cagM* with the prevalence of 71.8% was associated with increased density of *H. pylori* in corpus and higher total score for cor-

pus, but unrelated to the endoscopic diagnosis. Matar *et al.* correlated this gene with higher grade of gastritis and peptic ulcer disease (9). *LEC* (left end of *cagII*) was found in 48.5% of our isolates and was related to the lower prevalence of antrum atrophy. The *LEC* is rearranged more frequently in isolates linked to severe pathology (40).

This study comprised the patients without successful eradication of *H. pylori* infection after multiple antibiotic courses in spite of the fact that antimicrobial therapy was after one or two unsuccessful therapeutic outcomes created in accordance with antimicrobial susceptibility testing.

The most patients had normal or harmless endoscopic result (non-ulcer dyspepsia). Although pathological alterations did not point out to the danger of premalignant lesions our study found a high frequency of *cagA*, *ApCag*, *cagT* and *cagM* genes in the isolates recovered from the patients included in the study. The correlation between the presence of these genes and higher degree of serious pathohistological lesions in gastric mucosa was observed. According to the results of the present study it could be concluded that the presence of these genes can predispose for the development of ulcer, premalignant or malignant diseases. Thus, insisting on eradication of *H. pylori* in spite of harmless endoscopies and histological results should be considered as the only correct choice.

In spite of the fact that application of molecular diagnostics in detection of virulence genes is too expensive and not recommended for routine diagnostic, it should have a role in selected patients with unsuccessful eradication therapy with usual therapeutic protocols.

Moreover, the genomic profiles generated in this study may be useful for interlaboratory comparisons and are suitable for storage in epidemiological databases for comparative analyses. Our study has been focused on a specific group of patients isolates and may be representative for isolates from patients in this geographic region in Croatia. Future studies are needed to involve other disease specific strain group with appropriate controls.

CONFLICT OF INTEREST

There is no conflict of interest

FUNDING

The study was supported by the project of Croatian Ministry of Science, Sport and Education: *Helicobacter pylori* infection-evolution and new therapeutic approach; number: 108-000000-3114.

REFERENCES

1. CONTRERAS M, ABRANTE L, SALAZAR V, REYES N, GARCIA-AMADO MA, FERNANDEZ-DELGADO M, ROMERO R, ROJAS H, MICHELANGELI F 2014 Heterogene-

- ity of *cag* genotypes of *Helicobacter pylori* in the esophageal mucosa of dyspeptic patients and its relation to histopathological outcomes. *Int J of Inf Dis* 26:91–95
<http://dx.doi.org/10.1016/j.ijid.2014.03.1387>
2. LAI CH, PERNG CL, LAN KH, LIN HJ 2013 Association of IS605 and *cag*-PAI of *Helicobacter pylori* Isolated from Patients with Gastrointestinal Diseases in Taiwan. *Gastroenterology Research and Practise* ID 356217:1–5 <http://dx.doi.org/10.1155/2013/356217>
 3. LIMA VP, DE LIMA MA, FERREIRA MV, BAROS MA, RABENHORST SH 2010 The relationship between *Helicobacter pylori* genes *cagE* and *virB11* and gastric cancer. *Int J Infect Dis* 14:613–7 <http://dx.doi.org/10.1016/j.ijid.2009.09.006>
 4. BLASER MJ 2012 Heterogeneity of *Helicobacter pylori*. *Eur J Gastroenterol Hepatol* 9:53–7
<http://dx.doi.org/10.1097/00042737-201204001-00002>
 5. CENSINI S, LANGE C, XIANG Z, CRABTREE JE, GHIARA P, BORODOVSKY M, RAPPUOLI R, COVACCI A 1996 *CagA* pathogenicity island of *Helicobacter pylori*, encodes type I-specific and disease-associated virulence factors. *Proc Natl Acad Sci USA* 93:14648–14653 <http://dx.doi.org/10.1073/pnas.93.25.14648>
 6. XU X, LIU Z, FANG M, YU H, LIANG X, LIX, LIU X, CHEN C, JIA J 2012 *Helicobacter pylori CagA* induces ornithine decarboxylase upregulation via Src/MEK/ERK/c-Myc pathway: implication for progression of gastric diseases. *Exp. Biol. Med* 237:435–41
<http://dx.doi.org/10.1258/ebm.2011.011199>
 7. RAJASHREE P, SANTANU C, RONITA D, SIMANTI D, ABHIJIT C, RAMAMURTHY T, BALAKRISHN, DOUGLAS B, MUKHOPADHYAY A. K 2011 Intact *cag* pathogenicity island of *Helicobacter pylori* without disease association in Kolkata, India. *Int. Med. Microbiol* 301(4): 293–302
 8. BAGHAEI K, SHOKRZADEH L, JAFARI F, DABIRI H, YAMAOKA Y, BOLFIOM M, ZOJAJI H, ASLANI M, ZALI REZA M 2009 Determination of *Helicobacter pylori* virulence by analysis of the *cag* pathogenicity island isolates from Iranian population. *Dig. Liver Dis* 41(9):634–638
<http://dx.doi.org/10.1016/j.dld.2009.01.010>
 9. MATTAR R, MARQUES SB, MONTEIRO MS, DOS SANTOS AF, IRIYA K, CARRILHO FJ 2007 *Helicobacter pylori cag* pathogenicity island genes: clinical relevance for peptic ulcer disease development in Brazil 56:9–14
 10. KIDD M, LASTOVICA AJ, ATHERTON JC, LOUW JA 2001 Conservation of the *cag* pathogenicity island is associated with *vacA* alleles and gastroduodenal disease in South African *Helicobacter pylori* isolates. *Gut* 49:11–17
<http://dx.doi.org/10.1136/gut.49.1.11>
 11. COVACCI A, CENSINI S, BUGNOLI M, PETRACA R, BURRONI D, MACHIA D, MASSONE A, PAPINI E, XIANG Z, FIGURA N 1993 Molecular characterization of the 128-kDa immunodominant antigen of *Helicobacter pylori* associated with cytotoxicity and duodenal ulcer. *Proc Natl Acad Sci USA* 90(12): 5791–5795 <http://dx.doi.org/10.1073/pnas.90.12.5791>
 12. IKENOUE T, MAEDA S, GURA K, AKANUMA M, MITSUNO Y, IMAI Y, YOSHIDA H, SHIRATORI Y, OMATA M 2001 Determination of *Helicobacter pylori* virulence by simple gene analysis of the *cag* pathogenicity island. *Clin Diagn Lab Immunol* 8:181–186 <http://dx.doi.org/10.1128/cdli.8.1.181-186.2001>
 13. AKOPYANTS NS, CLIFTON SW, KERSULYTE D, CRABTREE JE, YOUREE BE, REECE CA, BUKANOV NO, DRAZEK ES, ROE BA, BERG DE 1998 Analyses of the *cag* pathogenicity island of *Helicobacter pylori*. *Mol Microbiol* 28:37–53 <http://dx.doi.org/10.1046/j.1365-2958.1998.00770.x>
 14. HAMMAR M, TYSZKIEWICZ T, WADSTROM T, OTOLE PW 1992 Rapid detection of *Helicobacter pylori* in gastric biopsy material by polymerase chain reaction. *J Clin Microbiol* 30:54–58
 15. DIXON MF, GENTA RM, YARDLEY JH, CORREA P 1996 Classification and grading of gastritis. The update Sydney System. International workshop on the Histopathology of Gastritis, Houston 1994. *Am J of Surg Pathology* 20(10):1161–1181
<http://dx.doi.org/10.1097/00000478-199610000-00001>
 16. ANTONIO-RINCON F, LOPEZ-VIDAL Y, CASTILLO-ROJAS G, LAZCANO-PONCE E, PONCE DE-LEON S, TABACHE-BARRERA M, AGUILAR GUTIERREZ G 2011 Pathogenicity island *cag*, *vacA* and IS605 genotypes in Mexican strains of *Helicobacter pylori* associated with peptic ulcers. *Annals of Clinical Microbiology and Antimicrobials* 10:18
<http://dx.doi.org/10.1186/1476-0711-10-18>
 17. SALIH BA, GUNERA, KARADEMIRA, USLU M, OVALI MA, YAZICI D, BOLEK BK, ARIKAN S 2014 Evaluation of the effect of *cag*PAI genes of *Helicobacter pylori* on AGS epithelial cell morphology and IL-8 secretion. *Antonie van Leeuwenhoek* 105:179–189 <http://dx.doi.org/10.1007/s10482-013-0064-5>
 18. NGUYEN LT, UCHIDA T, TSUKAMOTO Y, TRINH TD, TAL, MAI HB, LE HS, HO DQ, HOANG HH, MATSUHISA T, OKIMOTO T, KODAMA M, MURAKAMI K, FUJIJOA T, YAMAOKA Y, MORIYAMA M 2010 Clinical relevance of *cag*PAI intactness in *Helicobacter pylori* isolates from Vietnam. *Eur J Clin Microbiol Infect Dis* 29(6):651–660
<http://dx.doi.org/10.1007/s10096-010-0909-z>
 19. MAEDA S, YOSHIDA H, IKENOUE T, OGURA K, KANAI F, KATO N, SHIRATORI Y, OMATA M 1999 Structure of *cag* pathogenicity island in Japanese *Helicobacter pylori* isolates. *Gut* 44:336–341 <http://dx.doi.org/10.1136/gut.44.3.336>
 20. SOUOD N, KARGAR M, DOOSTI A, RANJBAR R, SARSHAR M 2013 Genetic Analysis of *cagA* and *vacA* genes in *Helicobacter pylori* isolates and their relationship with gastroduodenal diseases in the west of Iran. *Iran Red Crescent Med J* 15(5):371–375 <http://dx.doi.org/10.5812/ircmj.3732>
 21. WATADA M, SHIOTA S, MATSUNARI O, SUZUKI R, MURAKAMI K, FUJIJOA T, YAMAOKA Y 2011 Association between *Helicobacter pylori cagA*-related genes and clinical outcomes in Columbia and Japan. *BMC Gastroenterol* 11:5685–5692
<http://dx.doi.org/10.1186/1471-230X-11-141>
 22. BOYANOVA L, YORDANOV D, GERGOVA G, MARKOVSKA R, MITOV I 2011 Benefits of *Helicobacter pylori cagE* genotyping in addition to *cagA* genotyping: a Bulgarian study. *Antonie Van Leeuwenhoek* 100:529–535
<http://dx.doi.org/10.1007/s10482-011-9608-8>
 23. VAZIRI F, PEERAYEH S, ALEBOUYEH M, MIRZAEI T, YAMAOKA Y, MOLAEI M, MAGHSOUDI N, ZALI MR 2013 Diversity of *Helicobacter pylori* genotypes in Iranian patients with different gastroduodenal disorders. *World J Gastroenterol* 19(34):5685–5692 <http://dx.doi.org/10.3748/wjg.v19.i34.5685>
 24. HOMAN M, LUŽAR B, KOCIJAN BJ, OREL R, MOCILNIK T, SHRESTHA M, KVEDER M, POLJAK M 2009 Prevalence and clinical relevance of *cagA*, *vacA*, and *iceA* genotypes of *Helicobacter pylori* isolated from Slovenian children. *M J Pedijatr Gastroenterol Nutr* 49(3):289–96
<http://dx.doi.org/10.1097/MPG.0b013e31818f09f2>
 25. CHUNG C, OLIVARES A, TORRES E, YILMAZ O, COHEN H, PEREZ-PEREZ G 2010 Diversity of *VacA* Intermediate Region among *Helicobacter pylori* Strains from Several Regions of the World. *J Clin Microbiol* 48:690–696
<http://dx.doi.org/10.1128/JCM.01815-09>
 26. SASAKI T, HIRAI I, IZURIETA R, KWA BH, ESTEVEZ E, SALDANA A, CALZADA J, FUJIMOTO S, YAMAMOTO Y 2009 Analysis of *Helicobacter pylori* Genotype in Stool Specimens of Asymptomatic People. *Lab Med* 40:412–414
<http://dx.doi.org/10.1309/LM2Z2W/CDD2A9MFTNW>
 27. ALMEIDA N, DONATO MM, ROMAOZINHO JM, LUXO C, CARDOSO O, CIPRIANO MA, MARINHO C, FER-

- NANDES A, CARLOS S 2015 Correlation of *Helicobacter pylori* Genotypes with Gastric Histopathology in the Central Region of a South-European Country. *Dig Dis Sci* 60:74–85
<http://dx.doi.org/10.1007/s10620-014-3319-8>
28. FILIPEC-KANIŽAJ T, KATIČIĆ M, PRESEČKI S, GAŠPAROV S, COLIĆ CVRLJE V, KOLARIĆ B, MRZLJAK A 2009 Serum Antibodies Positivity to 12 *Helicobacter pylori* Virulence Antigens in Patients with Benign or Malignant Gastroduodenal Diseases—Cross-sectional Study. *Croat Med* 50: 124–132
<http://dx.doi.org/10.3325/cmj.2009.50.124>
 29. STRAUS EW, PATEL H, CHANG J, GUPTA RM, SOTTILE V, SCIRICA J, TARABAV G, IVER S, SAMUEL S, RAFFANELLO RD 2002 *H. pylori* Infection and Genotyping in Patients Undergoing Upper Endoscopy at Inner City Hospitals. *Dig Dis Sci* 47(7):1575–1581 <http://dx.doi.org/10.1023/A:1015827404901>
 30. MARIE MAM 2012 Relationship between *Helicobacter pylori* Virulence Genes and Clinical Outcomes in Saudi Patients. *J Korean Med Sci* 27:190–193
<http://dx.doi.org/10.3346/jkms.2012.27.2.190>
 31. HOSSEINI E, POURSINA F, VAN DE WIELE T, GHASEMIAN SAFAEI H, ADIBI P 2012 *Helicobacter pylori* in Iran: A systematic review on the association of genotypes and gastroduodenal diseases. *J Res Med Sci* 17(3):280–292
 32. DABIRI H, BOLFION M, MIRSALEHIAN A, REZADEHBASHI M, JAFARI F, SHOKRZADEH L, SAHEBEKHTIARI N, ZOJAJI H, YAMAOKA Y, MIRSATTARI D, ZALI MR 2010 Analysis of *Helicobacter pylori* genotypes in Afghani and Iranian isolates. *Pol J Microbiol* 59: 61–66
 33. SALIMZADEH L, BAGHERI N, ZAMANZAD B, AZADGAN-DEHKORDI F, RAHIMIAN G, HASHEMZADEH-CHALESHTORI M, RAFIEIAN-KOPAEI M, SANEI MH, SHIRZAD H 2015 Frequency of virulence factors in *Helicobacter pylori*-infected patients with gastritis. *Microb Pathog* 80:67–72
<http://dx.doi.org/10.1016/j.micpath.2015.01.008>
 34. BELDA S, SAEZ J, SANTIBANEZ M, RODRIGUEZ JC, SOLA-VERA J, RUIZ-GARCÍA M, BROTONS A, LÓPEZ-GIRONA E, PÉREZ E, SILLERO C, ROYO G 2012 Relationship between bacterial load, morbidity and *cagA* gene in patients infected by *Helicobacter pylori*. *Clin Microb Infect* 18:251–253
<http://dx.doi.org/10.1111/j.1469-0691.2012.03884.x>
 35. ATHERTON JC, THAM K, PEEK RM JR., COVER TL, BLASER MJ 1996 Density of *Helicobacter pylori* Infection in Vivo as Assessed by Quantitative Culture and Histology. *J Inf Diseases* 174(3):552–556
 36. BACKERT S, SCHWARZ T, MIEHLKE S, KIRSCH C, SOMMER C, KWOK T, GERHARD M, GOEBEL UB, LEHN N, KOENIG W, MEYER TF 2004 Functional analysis of the *cag* pathogenicity island in *Helicobacter pylori* isolates from patients with gastritis, peptic ulcer and gastric cancer. *Infect Immun* 72(2): 1043–1056 <http://dx.doi.org/10.1128/IAI.72.2.1043-1056.2004>
 37. MODENA P, SALES L, ACRANI G, RUSSO R, VILELA RIBEIRO MA, FUKUHARA Y, DA SILVEIRA WD, MÓDENA JL, DE OLIVEIRA RB, BROCCHI M 2007 Association between *Helicobacter pylori* genotypes and gastric disorders in relation to the *cag* pathogenicity island. *Diagn Microbiol Infect Dis* 59(1):7–16
<http://dx.doi.org/10.1016/j.diagmicrobio.2007.03.019>
 38. FISCHER W, PULS J, BUHRDORF R, GEBERT B, ODENBREIT S, HAAS R 2001 Systematic mutagenesis of the *Helicobacter pylori cag* pathogenicity island: essential genes for *CagA* translocation in host cells and induction of interleukin-8. *Mol. Microbiol* 42(5): 1337–48
<http://dx.doi.org/10.1046/j.1365-2958.2001.02714.x>
 39. KAUSER F, HUSSAIN MA, AHMED I, SRINIVAS S, DEVI SM, MAJEED AA, RAO KR, KHAN AA, SECHI LA, AHMED N 2005 Comparative genomics of *Helicobacter pylori* isolates recovered from ulcer disease patients in England. *BMC Microbiology* 5:32 <http://dx.doi.org/10.1186/1471-2180-5-32>
 40. KAUSER F, KHAN AA, HUSSAIN MA, CARROLI IM, AHMAD N, TIWARI S, SHOUCHE Y, DAS B, ALAM M, ALI SM, HABIBULLAH CM, SIERRA R, MEGRAUD F, SECHI LA, AHMED N 2004 The *cag* pathogenicity island of *Helicobacter pylori* is disrupted in the majority of patient isolates from different human population. *J Clin Microbiol* 40(11):5302–5308
<http://dx.doi.org/10.1128/JCM.42.11.5302-5308.2004>