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Helicobacter Pylori: Background, Diagnostic Methods and Nutritional Aspects

Helicobacter Pylori: Arka Plan, Tanı Yöntemleri ve Beslenme Yönleri

Vanessa Urie Kasum[1], Firdaus Hayati[1], Syed Sharizman Syed Abdul Rahim[2], Nik Amin Sahid Nik Lah[1], Serene En Hui Tung[3]

[1]Department of Surgery, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Sabah, Malaysia
[2]Department of Public Health Medicine, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Sabah, Malaysia
[3]Division of Nutrition and Dietetics, School of Health Sciences, International Medical University, Kuala Lumpur, Malaysia

ABSTRACT

Helicobacter pylori (*H. pylori*) bacteria have infected one-half of the world's population. The subset of *H. pylori* colonization with persistent inflammation is associated with an increased risk of developing gastritis, peptic ulcer disease, gastric cancer, and iron-deficiency anaemia. There are extra-gastric diseases that potentially can weaken the immune system and thus expose the host cells to bacterial infection. Accurate diagnosis of *H. pylori* infection is crucial for proper eradication treatment. There are several invasive and non-invasive methods available for *H. pylori* detection, and each of the methods has its advantages and disadvantages. In addition, nutritional status plays an important role in the progression of the *H. pylori* infection, which is further discussed in this review. We believe that there will be continuous improvements in the diagnostic methods and pharmaceutical treatments in the management of *H. pylori* infection. The emphasis on nutritional intake in the individual diet should also be implemented in the primary healthcare setting to reduce the incidence of *H. pylori* infection.

Keywords: Diagnosis, diet, eradication treatment, gastritis

ÖZ

Helicobacter pylori (*H. pylori*) bakterileri dünya nüfusunun yarısını enfekte etmiştir. *H. pylori* kolonizasyonunun kalıcı enflamasyona sahip alt kümesi, gastrit, peptik ülser hastalığı, mide kanseri ve demir eksikliği anemisi geliştirme riskinin artmasıyla ilişkilidir. Bağışıklık sistemini zayıflatabilecek ve böylece konak hücrelerini bakteriyel enfeksiyona maruz bırakabilecek gastrik dışı hastalıklar vardır. *H. pylori* enfeksiyonunun doğru teşhisi, uygun eradikasyon tedavisi için çok önemlidir. *H. pylori* tespiti için çeşitli invaziv ve non-invaziv yöntemler mevcuttur ve bu yöntemlerin her birinin avantajları ve dezavantajları vardır. Ek olarak, beslenme durumu *H. pylori* enfeksiyonunun ilerlemesinde önemli bir rol oynar ve bu incelemede daha ayrıntılı olarak ele alınmıştır. *H. pylori* enfeksiyonunun yönetiminde tanı yöntemlerinde ve farmasötik tedavilerde sürekli iyileştirmeler olacağına inanıyoruz. Bireysel diyette besin alımına vurgu, *H. pylori* enfeksiyonunun sıklığını azaltmak için birincil sağlık hizmeti ortamında da uygulanmalıdır.

Anahtar Sözcükler: Tanı, diyet, eradikasyon tedavisi, gastrit

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Address for Correspondence/Yazışma Adresi: Firdaus Hayati, MD, Department of Surgery, Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Sabah, Malaysia
E-mail / E-posta: m_firdaus@ums.edu.my
ORCID ID: orcid.org/0000-0002-3757-9744

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INTRODUCTION

Approximately one-half of the world's population is infected with *Helicobacter pylori (H. pylori)* (1). It has been estimated that *H. pylori* bacteria infect 90% of patients with duodenal ulcers and 80% of patients with gastric ulcers. *H. pylori* bacterium is a spiral gram-negative bacterium in a group called Epsilon proteobacteria class that can colonize the human stomach, especially the upper gastrointestinal tract site (2). The milestone discovery of *H. pylori* by Australian doctors, Barry J. Marshall and Robin Warren, has altered the diagnosis and treatment of stomach-related diseases (3). Although the curved bacteria had been reported, it was not until 1982 that Warren and Marshall identified the bacteria as the cause of chronic gastritis.

Initially, Marshall failed to develop an animal model for the experiments, so he decided to do a self-experiment by drinking a culture of the bacteria obtained from his patient (4). He developed nausea, vomiting, and achlorhydria 3 days after drinking the culture, and on day 8, the repeated endoscopy and biopsy results showed gastritis and positive *H. pylori* infection. He recovered with antibiotic and bismuth treatment, which eventually fulfilled Koch's third and fourth postulates for the role of *H. pylori* and gastritis. Koch's postulates were established to assess the microorganism that causes a disease (5). The bacteria were initially recognized as *Campylobacter pylori*, which was then renamed to *H. pylori,* as it has a helical physical structure and is mostly found in the pyloric region of the stomach (6).

H. pylori bacteria enter the body through oral and travel to the digestive system for colonization (7). It starts with a small subset of colonization and develops more serious outcomes over time, and massive colonization of *H. pylori* results in peptic ulcer, duodenal ulcer, or gastric cancer (8). The routes of transmission of *H. pylori* remain unclear. The most common routes of transmission are person-to-person, faecal-to-oral and environmental exposures (9). In developing countries, plausible environmental factors include untreated water, poor sanitation, and crowded living places that contribute to the spread of *H. pylori* bacteria (10).

Early research explained that person-to-person transmission occurs through two modes, namely, vertical and horizontal transmissions (11). The researchers explained that vertical transmission is spread among the same family members, while horizontal transmission involves contact from outside of the family or contaminated environments. The clustering of the *H. pylori* infection among family members is suggested to be due to genetic predisposition, close interpersonal contacts, and the same socioeconomic status (9). Dental plaque and saliva are typical means of transmission between family members (12).

The fact that *H. pylori* can survive in a pH environment as low as 1 and continue to create inflammation demonstrates its resilience (13). Figure 1 illustrates the anatomical structure of *H. pylori* bacteria and its function to induce inflammation in host cells. It can produce its cytoplasmic urease for enzymatic activity to convert urea to ammonia and carbon dioxide (14). The ammonia is responsible for neutralizing the acidic environment in the stomach to prevent the acid inhibition or damage of *H. pylori* bacteria. The presence of ammonia increases the pH in the gastric environment to protect the bacteria from gastric acid.

In contrast, *H. pylori* bacteria are unable to survive without urea at the extreme acidity (15). Due to urease activity, the gastric lining becomes less viscous, thus, allowing bacteria to adhere to the cells and colonize (16). *H. pylori* is a responsible agent that causes gastrointestinal diseases such as gastritis, peptic ulcer, duodenal ulcer, and stomach cancer (17). The severity of the disease depends on the immune system of the individual, the type of *H. pylori* strains, and environmental factors (18).

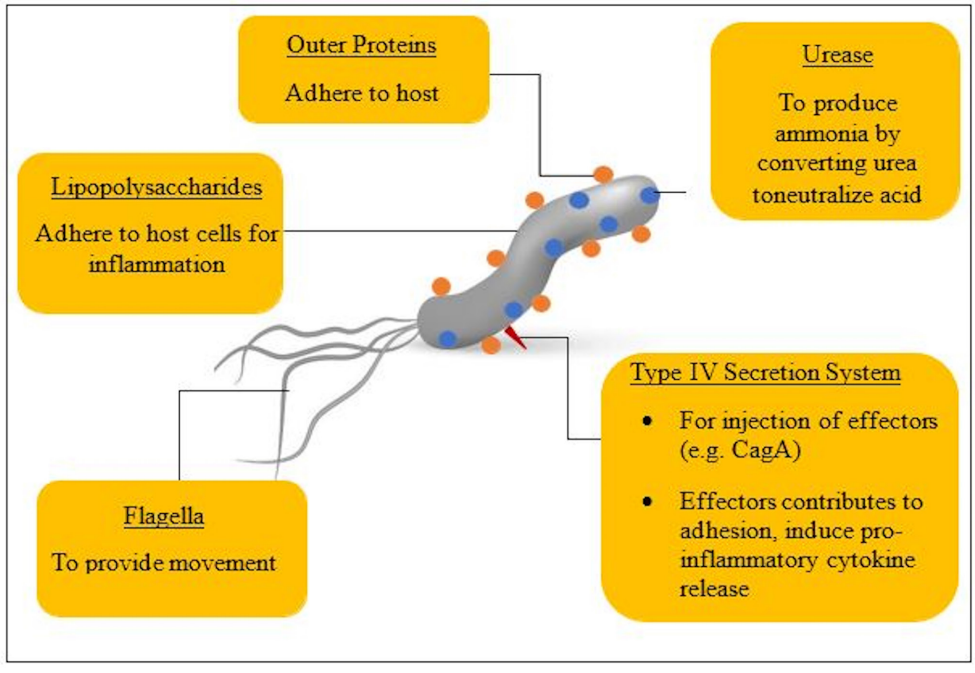

Figure 1. The anatomical structure of H. pylori bacteria and its function on host cells.
H. pylori: Helicobacter pylori

Diagnostic Test for *H. pylori* Infection

There are several methods to diagnose *H. pylori* infection. Each method has its advantages and disadvantages. An invasive test is biopsy-based that includes a rapid urease test (RUT), histological evaluation, and direct detection of *H. pylori* using polymerase chain reaction (PCR). On the other hand, there is also non-invasive treatment which includes serological tests, urea breath tests (UBT), and stool antigen tests (SAT). The comparison of the methods is provided in detail as shown in Table 1.

Rapid Urease Test

RUT can present the result in 1 hour, making it convenient for clinicians who need faster results (19). As mentioned, the principle of the RUT is based on the urease activity, which converts urea into ammonia and CO_2 to neutralize the gastric environment for its survival, increasing gastric pH. Most of the *H. pylori* specimens will become red or pink color after 50 minutes of exposure to the medium, indicating the production of the ammonium ion and increased pH (20). Overall, the specificity of the UBT is more than 95%, but sensitivity is more than 85%.

Table 1. The comparison of the invasive and non-invasive method in the detection of *H. pylori* infection

Type	Method	Features	Advantages	Disadvantages
Invasive	RUT	Sensitivity: >85% Specificity: >95%	• Easy, rapid and inexpensive • Sensitivity increases with increasing number of biopsies preferably from both gastric antrum and corpus • High accuracy in patient with peptic ulcer bleeding	• False-positive result as it can influence urease activity produce by other bacteria • False-negative result in patient with PPIs, bismuth, antibiotic and achlorhydria • Sensitivity decreases in the presence of the formalin contamination in the specimen
	Histology	Sensitivity: 60-90% Specificity: 75-100%	• The accuracy of the test increases with multiple biopsies (at least 2 biopsies) from the antrum and corpus • Able to detect the severity of the inflammation	• False-negative result in patients with PPIs and antibiotic • Unable to detect patchy *H. pylori* colonization
	PCR	Sensitivity: 80% Specificity: 100%	• Detect *H. pylori* instantly • Able to identify antimicrobial resistance	• Expensive and require high technology • False-positive resultas it can detect DNA in dead bacteria • False-negative result as it unable to detect *H. pylori* in coccoid form • Less accurate in the presence of heavy metals, proteins and polysaccharides complex
	Serological	Sensitivity: 80-90% Specificity: 80-90%	• Easy, rapid and inexpensive • High sensitivity in patient presented with gastric atrophy or on ump-proton inhibitors (PPIs) and antibiotic	• Unable to differentiate past and present infection • Less accurate in low prevalence region • False-positive result because of the influence by the positive predictive-value of antibody
Non-invasive	UBT	Sensitivity: >95% Specificity: >93%	• Widely available, cheap and easy to use • Convenience for elderly, children and pregnant women as it is requiring less radiation procedure • Gold standard to detect in asymptomatic individual	• Lack of data on antibiotic resistance • False-positive result that cause by other bacteria through urease activity • Less accuracy in patient on pump-proton inhibitors PPIs
	SAT	Sensitivity:>95% Specificity:>95%	• Less expensive and become second option when UBT no available • Not requiring high technology • Convenience as sample can be taken at home by the patient	• Less accurate if patient on antibiotic, altered bowel movement and underwent distal gastrectomy • Less accurate when the sample taken from unformed or watery stool

SAT: Stool antigen tests, UBT: Urea breath tests, *H. pylori: Helicobacter pylori*, PCR: Polymerase chain reaction, rapid urease test

The sensitivity of the test can be increased when more than 1 specimen is taken, preferably from the antrum and corpus of the gastric region (21). Additionally, RUT can be used in patients presenting with peptic ulcer bleeding. However, there are several limitations of RUT. First, RUT is influenced by bacterial urease concentration. Some cocci bacteria, such as *Staphylococci and Streptococci*, are involved in the production of urease activity, thus interfering with the detection of *H. pylori* bacteria (22). Secondly, RUT is influenced by antibiotics, pump-proton inhibitors (PPIs), bismuth, and achlorhydria, which can yield false-negative results (23). Hence, it is advisable to discontinue PPIs 2 weeks before, and antibiotics and bismuth 4 weeks before a UBT test (24). Finally, the RUT becomes less sensitive in the presence of formalin contamination in biopsy specimens.

Histological Evaluation

A histological test is the first method to detect *H. pylori*. It provides the assessment of the presence of *H. pylori* bacteria to the degree of inflammation caused by the infection (25). The use of the compound called Giemsa, hematoxylin, and eosin stains is sufficient to detect the *H. pylori* bacteria and the severity of the inflammation. However, several factors influence the accuracy of the test, including the site and number of biopsies (23). An increase in the number of biopsies can decrease the result of false-negative because histological tests are unable to detect patchy *H. pylori* colonization. Another factor that can yield a false-negative result is the use of PPIs and antibiotics, as these medications can change the form of *H. pylori* to its cocci form, making it unable to detect *H. pylori* (26).

Polymerase Chain Reaction

PCR is used to detect bacteria and to characterize bacterial genes and antimicrobial resistance (22). It allows researchers to detect *H. pylori* DNA in biopsy samples, and the PCR reaction mixture is prepared according to the manufacturer (27). PCR samples are not only limited to the biopsy but PCR have also been improved by using stool and saliva specimens. Modification of PCR technology has increased the sensitivity to 80% and specificity up to 100% (21). PCR has several advantages. It can detect *H. pylori* bacteria in a short period; hence, it offers convenience in a large sample size. Since the PCR can be used in the detection of antibiotic resistance, it can guide clinicians in suggesting antibiotic therapy for the eradication of *H. pylori* bacteria (28).

However, PCR tests cannot be used for daily detection of *H. pylori*, like UBT and SAT, because of high prices and the requirement of high-tech equipment. Since the principle of PCR is based on genetics, it also might produce false-positive results because it can detect the DNA from dead bacteria (29). On the other hand, a PCR test also can result in a false-negative as the test is unable to detect *H. pylori* in coccoid form. *H. pylori* can mutate the genes by changing its shape to a coccoid form to survive under environmental conditions such as extreme pH, very low or high temperature, and oxygen tension (26). Last but not least, the specificity of the PCR is reduced with the presence of heavy metal, protein, and polysaccharides complexes (30).

Serological Test

A serological test is used for the detection of anti-*H. pylori* IgG antibody for the diagnosis of *H. pylori* infection. Individuals infected with *H. pylori* usually present with specific antibodies such as IgG, IgA, and IgM, which can be detected via serological tests (9). IgG predominantly responds to the presence of chronic *H. pylori* infection (22). Serological tests are widely used in epidemiological studies because they are easy, rapid, and affordable. It also offers sensitivity and specificity in the range of 80% to 90%, and it depends on the individual's immune response, the duration of the exposure to the infection, nutritional status, and other antigen-related bacteria (22).

This rapid method also has high sensitivity in patients presenting with atrophy and is not influenced by antibiotics and PPIs; therefore, patients can continue taking the medications before the test (31). Serological tests have several disadvantages that limit their usefulness. This test cannot differentiate the past and present of the *H. pylori* infection; hence, it cannot be used to monitor the effectiveness of the eradication treatment (19). In fact, the serology result remains positive 3 years, after the treatment. The accuracy of the test is also lower in the low prevalence area which might produce false-positive result, thus further test by doing another diagnostic test such as histology, RUT and SAT to confirm the *H. pylori* infection (32).

Urea Breath Test

UBT, which is characterized by its high sensitivity and specificity, is widely available (9). However, the specificity of the UBT decreases among infants younger than 2 years old, as it requires active cooperation and often yields false-positive results (33). The first UBT test was reported 7 decades ago by American biochemist when they did experimental study by injecting C urea intravenously into anaesthetized cats that were not secreting gastric juice. They found out that the amount of C- CO_2 decreased in the breath and concluded that the colonization of *Helicobacter felis* bacteria was the culprit in the cat (34). The urease activity was abated after being treated with a mixture of penicillin, Terramycin, and sulphaguanidine in the cats.

Bacteria other than *H. pylori* are not present in the stomach except in patients with achlorhydria (35). As mentioned, *H. pylori* bacterium is involved in the mechanism that breaks down urea into ammonia and CO_2 (14). CO_2 enters the bloodstream and is subsequently exhaled in the lungs. Therefore, the CO_2 with the labelled C is measurable in the diagnosis of the *H. pylori* infection. Before conducting the UBT, a tablet containing urea is swallowed, and the amount of the trapped labelled-CO_2 is measurable in the exhalation. UBT offers a sensitivity of more than 95% and a specificity of more than 93%, with an affordable price (36). Besides, it can detect *H. pylori* bacteria in asymptomatic individuals, making it the gold standard for the diagnosis of *H. pylori* infection, especially among the elderly, children, and pregnant women, due to less radiation exposure (37). Although UBT has high sensitivity, there is a lack of data on antibiotic resistance that is important for eradication treatment (38). There is a chance of UBT yielding false-positive results that are induced by bacteria other than *H. pylori*, such as *Helicobacter heilmannii,* which is responsible for the process of urease activity (39). Patients who are on PPIs are also required to stop 2 weeks prior to UBT test because it can influence the results (31).

Stool Antigen Test

SAT is a non-invasive method that was introduced after the UBT test. The test is designed to detect the antigen associated with *H. pylori* in the stool (40). There are 2 types of SAT; one is based on enzyme immunoassay (EIA) and the other is based on immunochromatography

(ICA). Both tests yield high accuracy results, but in general, ICA provides less reliable results as compared to EIA (41). Early SAT used EIA based on polyclonal antibodies, which was then further improved by changing to monoclonal antibodies because they are more accurate with high sensitivity (42-43). The guidelines created by the Japanese researchers suggested that SAT has a sensitivity of more than 96% and a specificity of more than 97% before the eradication (44).

SAT is a relatively inexpensive non-invasive method as it requires fewer high-technology equipment to detect *H. pylori* bacteria in the stool sample (45). it offers convenience as patients can take the stool sample at home. SAT does not require discontinuation of PPI as does UBT because some monoclonal antibodies are not affected by PPIs. The SAT has disadvantages. Since the principle of the SAT is dependent on the antigen reaction, hence, it is less accurate when the sample is obtained from watery or unformed stool because the consistency of *H. pylori* specific antigen called serum pepsinogen I is diluted (46). SAT also has less accuracy in patients who underwent distal gastrectomy, with specificity decreased to 90.5%, altered bowel movements, and those on antibiotics and PPIs (21,47).

H. pylori Infection-Related Disease Outcomes

H. pylori bacteria are known to cause inflammation in the stomach region. This inflammation can lead to the development of diseases such as chronic gastritis, peptic ulcer disease, gastric cancer, iron-deficiency anaemia and diabetes mellitus (T2DM).

Chronic Gastritis

The primary infection of the *H. pylori* bacteria resulting in chronic gastritis is accompanied by epigastric pain and is sometimes asymptomatic (48). Gastritis is defined as inflammation of the gastric lining and can manifest as acute or chronic (49). Acute gastritis is temporary inflammation followed by clinical manifestations such as nausea, vomiting, and indigestion. *H. pylori* bacteria favor the antrum region of the stomach to start the colonization before migrating to another region (50). It often develops with the involvement of hypochloridria and neutrophil inflammatory cell infiltration (51). Researchers suggest that neutrophils are the marker in the development of gastric cancer, which has been examined with fluorescence RNA in situ. Chronic gastritis is divided into 2 categories: atrophic and non-atrophic, with the primary causal factor being *H. pylori* infection (52-53). Non-atrophic gastritis could progress to atrophic gastritis if proper treatment is not received by patients.

Peptic Ulcer

An early study found that 15% of *H. pylori*-infected individuals developed peptic ulcer disease (54). Symptoms of the peptic ulcer include nausea, vomiting, weight loss, and stomach bleeding (55). A peptic ulcer is a subset of the stomach and duodenum which extends into the submucosa (56). *H. pylori* bacteria cause inflammation, degeneration and injury to epithelial cells. Patients diagnosed with peptic ulcer disease are recommended to proceed with diagnostic tests for *H. pylori* bacteria because peptic ulcer can also be induced by non-steroidal anti-inflammatory drugs that are commonly used to relieve pain and reduce inflammation (57,58).

Gastric Cancer

H. pylori infection is one of the strongest factors in the development of gastric cancer. *H. pylori* bacteria are persistent in producing inflammation in the stomach, which weakens the immune response if left untreated (59). Prolonged exposure to the inflammatory response predisposes gastric cells to become cancer (60). The inflammatory compounds attack healthy tissue and cause alteration in the DNA transcription hence resulting in DNA damage (61). This is the initial stage of gastric cancer. Further steps in the pathway are to promote cell proliferation and produce more reactive oxygen species that further damage the DNA and decrease the efficiency of DNA repair, resulting in cancer cell development (62).

Type 2 Diabetes Mellitus

A meta-analysis found that *H. pylori* bacteria increased the risk of T2DM by 27% (63). T2DM is characterized by insulin deficiency or insulin resistance (64). Insulin is a hormone that is secreted by the pancreas to maintain glucose homeostasis. In the cross-sectional study conducted in Cameroon, central region of Africa, about 73% of the subjects with *H. pylori* infection were diagnosed with T2DM (65). Infected patients with body mass index (BMI) of more than 25kg/m^2 are more prone to develop T2DM compared to infected patients with normal BMI in the range of 18.5 to 24.9kg/m^2. Symptoms vary and include dysphagia, early satiety, nausea and vomiting (66).

The pathogenesis of *H. pylori* in relation to T2DM is interesting. Gastritis related to *H. pylori* alters the secretion of hormones called gastrin and somatostatin (67). Gastrin stimulates the production of insulin while somatostatin decreases the production of insulin. *H. pylori* acts to promote the production of somatostatin and reduce gastrin, causing a decrease in the production of insulin and increasing the susceptibility of insulin to oxidative stress and inflammatory mediators (68-69). Other evidence indicates that T2DM itself can increase the risk of *H. pylori* infection because T2DM can impair the immune system of host cells, thus, increasing the susceptibility of infection (70). Besides, gastric motility is often disrupted in patients with T2DM, thereby increasing the risk of *H. pylori* colonization and inducing inflammation (71).

Iron-deficiency Anemia

Chronic gastritis related to *H. pylori* infection is closely associated with impairment of iron absorption, resulting in iron deficiency, anemia, and vitamin B12 deficiency (72). This clinical manifestation resulted from hypochlorhydria in the stomach, which subsequently impairs the absorption of dietary iron, which is necessary to metabolize ferric into ferrous form. *H. pylori* uses iron for its colonization and increases the production of hepcidin (73). The hormone hepcidin is released by the liver for iron metabolism. A reduction in the intragastric pH affects iron absorption from the diet (74). This has been demonstrated in the study conducted among school-aged children with *H. pylori* infection, who presented with elevated hepcidin levels and iron deficiency, compared to non-infected children (75).

Treatment For *H. pylori* Infection

H. pylori infection is often treated with antibiotics for a minimum of 2 weeks (76). The treatment also usually will include medication such as PPIs and bismuth subsalicylate, to help in the healing process by coating the ulcer base and protecting the stomach from further acid exposure (26,77).

H. pylori Infection and Nutrition

Nutrition plays an important role in maintaining ecology in the gastric environment (2). The health ecology in the gastric environment is

highly influenced by the host's diet. The contribution of the nutrients to *H. pylori* is explained in detail as follows:

Salt

High intake of salt is associated with an increase in the risk of *H. pylori* infection and development of pre-malignancy (78). The consumption of salt in high amounts can destroy the gastric mucosal barrier, resulting in inflammation and, thus, favor colonization by *H. pylori* bacteria (79). One of the potential pathways is that high salt intake alters the viscosity and integrity of gastric mucosa, thus, promoting the colonization of *H. pylori* colonization and persistent inflammation forming gastric proliferation and mutation in DNA (80). This has been demonstrated well in an early animal study whereby a high salt diet modifies the structure of gastric mucosa via an inflammatory process in mice infected with *H. pylori* (81). The loss of parietal cells, which secrete gastric acid, creates an achlorhydria environment, exacerbates the colonization of *H. pylori,* and enhances the process of carcinogenesis (82). Another interesting animal experimental study was conducted where researchers introduced a diet with a high concentration of salt, 87.5% sodium chloride, to Mongolian gerbils (83). 87.5% of sodium chloride is the starting concentration, approximately equivalent to 3 to 20% of salt in salted fish, 25% of salt in pickles, and 19% of salt in soy sauce. This mixture was given to the gerbil with no variation over a prolonged period. Over 60% of the gerbils were infected with cagA+ *H. pylori* strain within 4 months of interventions.

Zinc

Zinc plays a pivotal role in the maintenance of DNA integrity, synthesis, repair and cell division (84). It is also involved in the defense mechanism to protect DNA from oxidative stress. Deficiency of zinc can impede DNA damage through the production of oxidative stress mediators and impair its role as a DNA repair agent. Previous studies clearly demonstrated the relationship between zinc deficiency and the role of *H. pylori* infection in the human mechanism (85). This has been confirmed in the case-control study whereby the *H. pylori*-infected group, presented with gastritis, peptic ulcer, and gastric cancer, having a lower level of serum zinc compared to the healthy control group (86).

H. pylori bacteria require zinc for nutrition to support its growth and colonization; thus, it needs to compete with calprotectin (87). Calprotectin is a zinc-binding protein that can be found in neutrophils, and the presence of calprotectin in the stomach region is closely related to the inflammatory response (88). It is released into the gut to chelate with zinc in response to bacterial infection. In response to calprotectin, the *H. pylori* bacterium alters its structure to decrease cell surface hydrophobicity to enhance its fitness in the presence of calprotectin to response when there is availability of the zinc (89). In the state of zinc deficiency, this increases susceptibility to inflammatory response, gastric inflammation, and DNA damage in the host cells.

Vitamin C

Adequate intake of vitamin C acts as a defence mechanism against infection. It is believed that high intake of vitamin C from fruits and vegetable sources reduces the risk of H. pylori infection (90). The antioxidant role of vitamin C is to protect the gastric mucosa from the inflammation caused by *H. pylori* infection, and it also reduce the production of carcinogens to prevent the colonization of *H. pylori* bacteria (91). Vitamin C has been shown to play a crucial role in inhibiting the activity of neutrophils induced by *H. pylori* infection (92). It has been demonstrated well in the study that the level of vitamin C in gastric acid and serum is lower in *H. pylori*-infected patients with gastritis and peptic ulcers (93).

In addition, vitamin C has been used as part of treatment to eradicate *H. pylori* (94). Whether increased vitamin C levels during the eradication period from intake of natural fruits and vegetables, along with the addition of vitamin C supplementation, increase the effectiveness of therapy is still a controversial issue. Normal dietary intake of vitamin C, about 40mg per day from fruits and vegetables, allows vitamin C to play its role as an antioxidant and enzymatic cofactor (95). Thus, nutritional management and education emphasizing a high daily intake of fruits and vegetables are important, especially among *H. pylori*-infected populations.

Probiotics

Probiotic bacteria called Lactobacillus and Bifidobacterium can be found widely in probiotic yoghurt drinks. The supplementation of probiotics during the *H. pylori* eradication period has improved the rate of success (96). Supplementation of probiotics by consuming yoghurt drinks two times a day for 6 months demonstrates a decrease in *H. pylori* urease compared to the infected group that only supplemented with milk (97). A meta-analysis examined The effect of Lactobacillus bacteria and reported that it improves by approximately 10 percent over placebo before antibiotic drug therapy (98). It plays a role as an antioxidant and an anti-inflammatory agent that later explains its role in decreasing stabilizing the gastric barrier (99).

The mechanism of probiotics against the severity of *H. pylori* infection is still unclear. However, a few researchers have suggested that probiotics may help in producing mucin to strengthen the gastric barrier and compete with *H. pylori* bacteria for adhesion receptors, as well as stabilize the gut barrier to prevent bacterial colonization (100). Moreover, Lactobacillus displays similar characteristics to *H. pylori* as both can survive in low pH environments in the stomach and protect the gut from inflammation induced by *H. pylori* bacteria (101). The longer the duration of yoghurt consumption, the better the effect in decreasing the density of *H. pylori* colonization in the gut (100). Intake of yoghurt in the long term was found to be a safe and effective strategy to prevent an infection.

CONCLUSION

The development of the current methods to detect *H. pylori* bacteria allows more accurate diagnosis of *H. pylori* infection to combat the disease outcomes associated with it. An accurate diagnosis helps to guide clinicians in choosing the appropriate eradication treatment for infected *H. pylori* individuals. The selection of the method depends on the sample size, the location, the clinical manifestation of the infected individual, and the pros and cons of the methods. The selection of more than one method is advisable in certain circumstances to further confirm the *H. pylori* diagnosis. Importantly, the nutritional status of the individual should not be overlooked as it undoubtedly influences disease outcomes related to *H. pylori* infection. We believe that there would be continuous improvement in the diagnostic method and

pharmaceutical treatment in the management of *H. pylori* infection. The emphasis on nutritional intake in the individual diet also should be implemented in the primary healthcare setting to reduce the incidence of *H. pylori* infection.

Footnotes

Authorship Contributions

Surgical and Medical Practices: F.H., N.A.S.N.L., Concept: S.S.S.A.R., Design: Data Collection or Processing:Analysis or Interpretation:Literature Search: F.H., S.E.H.T., Writing: V.U.K.

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REFERENCES

1. Correa P, Piazuelo MB. Natural history of *Helicobacter pylori* infection. Dig Liver Dis. 2008; 40: 490-6.
2. Haley KP, Gaddy JA. Nutrition and *Helicobacter pylori*: host diet and nutritional immunity influence bacterial virulence and disease outcome. Gastroenterol Res Pract. 2016; 2016: 3019362.
3. Warren JR, Marshall B. Unidentified curved bacilli on gastric epithelium in active chronic gastritis. Lancet. 1983; 1: 1273-5.
4. Marshall BJ, Armstrong JA, McGechie DB, Glancy RJ. Attempt to fulfil Koch's postulates for pyloric *Campylobacter*. Med J Aust. 1985; 142: 436-9.
5. Segre JA. What does it take to satisfy Koch's postulates two centuries later? Microbial genomics and *Propionibacteria* acnes. J Invest Dermatol. 2013; 133: 2141-2.
6. Goodwin CS, Worsley BW. Microbiology of *Helicobacter pylori*. Gastroenterol Clin North Am. 1993; 22: 5-19.
7. Bravo D, Hoare A, Soto C, Valenzuela MA, Quest AF. *Helicobacter pylori* in human health and disease: Mechanisms for local gastric and systemic effects. World J Gastroenterol. 2018; 24: 3071-89.
8. Xia Y, Meng G, Zhang Q, Liu L, Wu H, Shi H, et al. Dietary patterns are associated with *helicobacter pylori* infection in chinese adults: a cross-sectional study. Sci Rep. 2016; 6: 32334.
9. Kayali S, Aloe R, Bonaguri C, Gaiani F, Manfredi M, Leandro G, et al. Non-invasive tests for the diagnosis of *helicobacter pylori*: state of the art. Acta Biomed. 2018; 89: 58-64.
10. Krueger WS, Hilborn ED, Converse RR, Wade TJ. Environmental risk factors associated with *Helicobacter pylori* seroprevalence in the United States: a cross-sectional analysis of NHANES data. Epidemiol Infect. 2015; 143: 2520-31.
11. Rothenbacher D, Bode G, Berg G, Knayer U, Gonser T, Adler G, et al. *Helicobacter pylori* among preschool children and their parents: evidence of parent-child transmission. J Infect Dis. 1999; 179: 398-402.
12. Goh KL, Chan WK, Shiota S, Yamaoka Y. Epidemiology of *Helicobacter pylori* infection and public health implications. Helicobacter. 2011; 16 Suppl 1: 1-9.
13. Ansari S, Yamaoka Y. Survival of *Helicobacter pylori* in gastric acidic territory. Helicobacter. 2017; 22: 10.1111/hel.12386.
14. Berger A. Scientists discover how helicobacter survives gastric acid. BMJ. 2000; 320: 268.
15. Su-Arcaro C, Liao W, Bieniek K, Constantino MA, Decker SM, Turner BS, et al. Unraveling the intertwined effect of pH on *Helicobacter pylori* motility and the microrheology of the mucin-based medium it swims in microorganisms. 2023; 11: 2745.
16. Celli JP, Turner BS, Afdhal NH, Keates S, Ghiran I, Kelly CP, et al. *Helicobacter pylori* moves through mucus by reducing mucin viscoelasticity. Proc Natl Acad Sci U S A. 2009; 106: 14321-6.
17. Ruggiero P. *Helicobacter pylori* and inflammation. Curr Pharm Des. 2010; 16: 4225-36.
18. Krzyżek P, Gościniak G. Morphology of *Helicobacter pylori* as a result of peptidoglycan and cytoskeleton rearrangements. Prz Gastroenterol. 2018; 13: 182-95.
19. Chey WD, Wong BC; Practice Parameters Committee of the American College of Gastroenterology. American College of Gastroenterology guideline on the management of *Helicobacter pylori* infection. Am J Gastroenterol. 2007; 102: 1808-25.
20. Uotani T, Graham DY. Diagnosis of *Helicobacter pylori* using the rapid urease test. Ann Transl Med. 2015; 3: 9.
21. Talebi Bezmin Abadi A. Diagnosis of *Helicobacter pylori* using invasive and noninvasive approaches. J Pathog. 2018; 2018: 9064952.
22. Patel SK, Pratap CB, Jain AK, Gulati AK, Nath G. Diagnosis of *Helicobacter pylori:* what should be the gold standard? World J gastroenterol. 2014; 20: 12847-59.
23. Wang YK, Kuo FC, Liu CJ, Wu MC, Shih HY, Wang SS, et al. Diagnosis of *Helicobacter pylori* infection: current options and developments. World J Gastroenterol. 2015; 21: 11221-35.
24. Sankararaman S, Moosavi L. Urea Breath Test. 2024. In: StatPearls [Internet].
25. Lee JY, Kim N. Diagnosis of *Helicobacter pylori* by invasive test: histology. Ann Transl Med. 2015;3:10.
26. Ierardi E, Losurdo G, Fortezza RF, Principi M, Barone M, Leo AD. Optimizing proton pump inhibitors in *Helicobacter pylori* treatment: Old and new tricks to improve effectiveness. World J Gastroenterol. 2019; 25: 5097-104.
27. Cosgun Y, Yildirim A, Yucel M, Karakoc AE, Koca G, Gonultas A, et al. Evaluation of invasive and noninvasive methods for the diagnosis of *Helicobacter pylori* infection. Asian Pac J Cancer Prev. 2016; 17: 5265-72.
28. Marrero Rolon R, Cunningham SA, Mandrekar JN, Polo ET, Patel R. Clinical evaluation of a real-time PCR assay for simultaneous detection of *Helicobacter pylori* and genotypic markers of clarithromycin resistance directly from stool. J Clin Microbiol. 2021; 59: e03040-20.
29. He Q, Wang JP, Osato M, Lachman LB. Real-time quantitative PCR for detection of *Helicobacter pylori*. J Clin Microbiol. 2002; 40: 3720-8.
30. Giorgio F, Ierardi E, Sorrentino C, Principi M, Barone M, Losurdo G, et al. *Helicobacter pylori* DNA isolation in the stool: an essential pre-requisite for bacterial noninvasive molecular analysis. Scand J Gastroenterol. 2016; 51: 1429-32.
31. Malfertheiner P, Megraud F, O'Morain CA, Atherton J, Axon AT, Bazzoli F, et al. Management of *Helicobacter pylori* infection-the maastricht iv/ florence consensus report. Gut. 2012; 61: 646-64.
32. Miftahussurur M, Yamaoka Y. Diagnostic methods of *Helicobacter pylori* infection for epidemiological studies: critical importance of indirect test validation. Biomed Res Int. 2016; 2016: 4819423.
33. Imrie C, Rowland M, Bourke B, Drumm B. Limitations to carbon 13-labeled urea breath testing for *Helicobacter pylori* in infants. J Pediatr. 2001; 139: 734-7.
34. Kornberg HL, Davies RE, Wood DR. The breakdown of urea in cats not secreting gastric juice. Biochem J. 1954; 56: 355-63.
35. Sabbagh P, Mohammadnia-Afrouzi M, Javanian M, Babazadeh A, Koppolu V, Vasigala VR, et al. Diagnostic methods for *Helicobacter pylori* infection: ideals, options, and limitations. Eur J Clin Microbiol Infect Dis. 2019; 38: 55-66.

36. Niv Y, Hazazi R. *Helicobacter pylori* recurrence in developed and developing countries: meta-analysis of 13C-urea breath test follow-up after eradication. Helicobacter. 2008; 13: 56-61.
37. Metanat HA, Valizadeh SM, Fakheri H, Maleki I, Taghvaei T, Hosseini V, et al. Comparison between 10- and 14-day hybrid regimens for *helicobacter pylori* eradication: a randomized clinical trial. Helicobacter. 2015; 20: 299-304.
38. De Francesco V, Zullo A, Perna F, Giorgio F, Hassan C, Vannella L, et al. *Helicobacter pylori* antibiotic resistance and [13C] urea breath test values. J Med Microbiol. 2010; 59: 588-91.
39. Osaki T, Mabe K, Hanawa T, Kamiya S. Urease-positive bacteria in the stomach induce a false-positive reaction in a urea breath test for diagnosis of *Helicobacter pylori* infection. J Med Microbiol. 2008; 57: 814-9.
40. Qiu E, Li Z, Han S. Methods for detection of *Helicobacter pylori* from stool sample: current options and developments. Braz J Microbiol. 2021; 52: 2057-62.
41. Korkmaz H, Kesli R, Karabagli P, Terzi Y. Comparison of the diagnostic accuracy of five different stool antigen tests for the diagnosis of *Helicobacter pylori* infection. Helicobacter. 2013; 18: 384-91.
42. Gisbert JP, de la Morena F, Abraira V. Accuracy of monoclonal stool antigen test for the diagnosis of *H. pylori* infection: a systematic review and meta-analysis. Am J Gastroenterol. 2006; 101: 1921-30.
43. Deguchi R, Matsushima M, Suzuki T, Mine T, Fukuda R, Nishina M, et al. Comparison of a monoclonal with a polyclonal antibody-based enzyme immunoassay stool test in diagnosing *Helicobacter pylori* infection after eradication therapy. J Gastroenterol. 2009; 44: 713-6.
44. Kato M, Ota H, Okuda M, Kikuchi S, Satoh K, Shimoyama T, et al. Guidelines for the management of *Helicobacter pylori* infection in Japan: 2016 Revised Edition. Helicobacter. 2019; 24: e12597.
45. Shimoyama T. Stool antigen tests for the management of *Helicobacter pylori* infection. World J Gastroenterol. 2013; 19: 8188-91.
46. Moon HW, Lee SY, Hur M, Yun YM. Characteristics of *Helicobacter pylori*-seropositive subjects according to the stool antigen test findings: a prospective study. Korean J Intern Med. 2018; 33: 893-901.
47. Yan J, Yamaguchi T, Odaka T, Suzuki T, Ohyama N, Hara T, et al. Stool antigen test is a reliable method to detect *Helicobacter pylori* in the gastric remnant after distal gastrectomy for gastric cancer. J Clin Gastroenterol. 2010; 44: 73-4.
48. Khan Z, Gul A. *Helicobacter Pylori*-associated gastritis in Middle Eastern patients: a case series. Cureus. 2023; 15: e39145.
49. Azer SA, Awosika AO, Akhondi H. Gastritis. 2024 Jun 22. In: StatPearls [Internet].
50. Kate V, Maroju NK, Ananthakrishnan N. *Helicobacter pylori* infection and upper gastrointestinal disorders. Gastroenterol Res Pract. 2013; 2013: 896209.
51. Fu H, Ma Y, Yang M, Zhang C, Huang H, Xia Y, et al. Persisting and increasing neutrophil infiltration associates with gastric carcinogenesis and e-cadherin downregulation. Sci Rep. 2016; 6: 29762.
52. Kayaçetin S, Güreşçi S. What is gastritis? What is gastropathy? How is it classified? Turk J Gastroenterol. 2014; 25: 233-47.
53. Sipponen P, Maaroos HI. Chronic gastritis. Scand J Gastroenterol. 2015; 50: 657-67.
54. Logan RP, Walker MM. ABC of the upper gastrointestinal tract: Epidemiology and diagnosis of *Helicobacter pylori* infection. BMJ. 2001; 323: 920-2.
55. Narayanan M, Reddy KM, Marsicano E. Peptic Ulcer Disease and *Helicobacter pylori* infection. Mo Med. 2018; 115: 219-24.
56. Feldman M, Friedman LS, Brandt LJ. Sleisenger and Fordtran's Gastrointestinal and liver disease e-book: pathophysiology, diagnosis, management, expert consult premium edition-enhanced online features. Saunders; 2010. Available from: https://www.amazon.com/Sleisenger-Fordtrans-Gastrointestinal-Liver-Disease/dp/1416061894
57. Zhang BB, Li Y, Liu XQ, Wang PJ, Yang B, Bian DL. Association between vacA genotypes and the risk of duodenal ulcer: a meta-analysis. Mol Biol Rep. 2014; 41: 7241-54.
58. Ghlichloo I, Gerriets V. Nonsteroidal anti-inflammatory drugs (NSAIDs). 2023 May 1. In: StatPearls [Internet].
59. Wroblewski LE, Peek RM Jr, Wilson KT. *Helicobacter pylori* and gastric cancer: factors that modulate disease risk. Clin Microbiol Rev. 2010; 23: 713-39.
60. Miftahussurur M, Yamaoka Y, Graham DY. *Helicobacter pylori* as an oncogenic pathogen, revisited. Expert Rev Mol Med. 2017; 19: e4.
61. Jaroenlapnopparat A, Bhatia K, Coban S. Inflammation and gastric cancer. Diseases. 2022; 10: 35.
62. Alhmoud JF, Woolley JF, Al Moustafa AE, Malki MI. DNA Damage/repair management in cancers. Cancers (Basel). 2020; 12: 1050.
63. Mansori K, Moradi Y, Naderpour S, Rashti R, Moghaddam AB, Saed L, et al. *Helicobacter pylori* infection as a risk factor for diabetes: a meta-analysis of case-control studies. BMC Gastroenterol. 2020; 20: 77.
64. Goyal R, Singhal M, Jialal I. Type 2 Diabetes. 2023 Jun 23. In: StatPearls [Internet].
65. Kouitcheu Mabeku LB, Noundjeu Ngamga ML, Leundji H. *Helicobacter pylori* infection, a risk factor for Type 2 diabetes mellitus: a hospital-based cross-sectional study among dyspeptic patients in Douala-Cameroon. Sci Rep. 2020; 10: 12141.
66. Bakka AS, Salih BA. Prevalence of *Helicobacter pylori* infection in asymptomatic subjects in Libya. Diagn Microbiol Infect Dis. 2002; 43: 265-8.
67. Kaneko H, Konagaya T, Kusugami K. *Helicobacter pylori* and gut hormones. J Gastroenterol. 2002; 37: 77-86.
68. Rahman MA, Cope MB, Sarker SA, Garvey WT, Chaudhury HS, Khaled MA. *Helicobacter pylori* infection and inflammation: implication for the pathophysiology of diabetes and coronary heart disease in Asian Indians. J Life Sci. 2009; 1: 45-50.
69. Hosseininasab Nodoushan SA, Nabavi A. The interaction of *Helicobacter pylori* infection and type 2 diabetes mellitus. Adv Biomed Res. 2019; 8: 15.
70. Berbudi A, Rahmadika N, Tjahjadi AI, Ruslami R. Type 2 diabetes and its impact on the immune system. Curr Diabetes Rev. 2020; 16: 442-9.
71. Watson LE, Xie C, Wang X, Li Z, Phillips LK, Sun Z, et al. Gastric emptying in patients with well-controlled type 2 diabetes compared with young and older control subjects without diabetes. J Clin Endocrinol Metab. 2019; 104: 3311-9.
72. Hudak L, Jaraisy A, Haj S, Muhsen K. An updated systematic review and meta-analysis on the association between *Helicobacter pylori* infection and iron deficiency anemia. Helicobacter. 2017; 22.
73. Campuzano-Maya G. Hematologic manifestations of *Helicobacter pylori* infection. World J Gastroenterol. 2014; 20: 12818-38.
74. Stein J, Connor S, Virgin G, Ong DE, Pereyra L. Anemia and iron deficiency in gastrointestinal and liver conditions. World J Gastroenterol. 2016; 22: 7908-25.
75. Mendoza E, Duque X, Hernández Franco JI, Reyes Maldonado E, Morán S, Martínez G, et al. Association between active *H. pylori* infection and iron deficiency assessed by serum hepcidin levels in school-age children. Nutrients. 2019; 11: 2141.

76. Goh KL, Lee YY, Leow AH, Ali RAR, Ho SH, Mahadeva S, et al. A Malaysian consensus report on the diagnosis and treatment of *Helicobacter pylori* infection. JGH Open. 2023; 7: 261-71.
77. Graham DY, Lee SY. How to effectively use bismuth quadruple therapy: the good, the bad, and the ugly. Gastroenterol Clin North Am. 2015; 44: 537-63.
78. Monteiro C, Costa AR, Peleteiro B. Sodium intake and *Helicobacter pylori* infection in the early stages of life. Porto Biomed J. 2016; 1: 52-8.
79. Mard SA, Khadem Haghighian H, Sebghatulahi V, Ahmadi B. Dietary factors in relation to *helicobacter pylori* infection. Gastroenterol Res Pract. 2014; 2014: 826910.
80. Balendra V, Amoroso C, Galassi B, Esposto J, Bareggi C, Luu J, et al. High-Salt Diet Exacerbates *H. pylori* Infection and Increases Gastric Cancer Risks. J Pers Med. 2023; 13: 1325.
81. Fox JG, Dangler CA, Taylor NS, King A, Koh TJ, Wang TC. High-salt diet induces gastric epithelial hyperplasia and parietal cell loss, and enhances *Helicobacter pylori* colonization in C57BL/6 mice. Cancer Res. 1999; 59: 4823-8.
82. Gaddy JA, Radin JN, Loh JT, Zhang F, Washington MK, Peek RM Jr, et al. High dietary salt intake exacerbates *Helicobacter pylori*-induced gastric carcinogenesis. Infect Immun. 2013; 81: 2258-67.
83. Kato S, Tsukamoto T, Mizoshita T, Tanaka H, Kumagai T, Ota H, et al. High salt diets dose-dependently promote gastric chemical carcinogenesis in *Helicobacter pylori*-infected Mongolian gerbils associated with a shift in mucin production from glandular to surface mucous cells. Int J Cancer. 2006; 119: 1558-66.
84. Song Y, Leonard SW, Traber MG, Ho E. Zinc deficiency affects DNA damage, oxidative stress, antioxidant defenses, and DNA repair in rats. J Nutr. 2009; 139: 1626-31. Avilable from: https://pubmed.ncbi.nlm.nih.gov/19625698/
85. Wong CP, Magnusson KR, Sharpton TJ, Ho E. Effects of zinc status on age-related T cell dysfunction and chronic inflammation. Biometals. 2021 Apr; 34: 291-301. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC8559905/
86. Tao H, Meng F, Zhou Y, Fan J, Liu J, Han Y, et al. Transcriptomic and functional approaches unveil the role of tmRNA in zinc acetate mediated levofloxacin sensitivity in *Helicobacter pylori*. Microbiol Spectr. 2022; 10: e0115222.
87. Zhang WH, Wu XJ, Niu JX, Yan H, Wang XZ, Yin XD, et al. Serum zinc status and *Helicobacter pylori* infection in gastric disease patients. Asian Pac J Cancer Prev. 2012; 13: 5043-6.
88. Haley KP, Delgado AG, Piazuelo MB, Mortensen BL, Correa P, Damo SM, et al. The human antimicrobial protein calgranulin C participates in control of *helicobacter pylori* growth and regulation of virulence. Infect Immun. 2015; 83: 2944-56.
89. Pathirana WGW, Chubb SP, Gillett MJ, Vasikaran SD. Faecal calprotectin. Clin Biochem Rev. 2018; 39: 77-90.
90. Gaddy JA, Radin JN, Cullen TW, Chazin WJ, Skaar EP, Trent MS, et al. *Helicobacter pylori* resists the antimicrobial activity of calprotectin via lipid a modification and associated biofilm Formation. mBio. 2015; 6: e01349-15.
91. Jarosz M, Rychlik E, Siuba M, Respondek W, Ryzko-Skiba M, Sajór I, et al. Dietary and socio-economic factors in relation to *Helicobacter pylori* re-infection. World J Gastroenterol. 2009; 15: 1119-25.
92. Zhang ZW, Farthing MJ. The roles of vitamin C in *Helicobacter pylori* associated gastric carcinogenesis. Chin J Dig Dis. 2005; 6: 53-8.
93. Wang T, Cai H, Sasazuki S, Tsugane S, Zheng W, Cho ER, et al. Fruit and vegetable consumption, *Helicobacter pylori* antibodies, and gastric cancer risk: a pooled analysis of prospective studies in China, Japan, and Korea. Int J Cancer. 2017; 140: 591-9.
94. Mei H, Tu H. Vitamin C and *Helicobacter pylori* infection: current knowledge and future prospects. Front Physiol. 2018; 9: 1103.
95. Hussain A, Tabrez E, Peela J, Honnavar P Dr, Tabrez SSM. Vitamin C: a preventative, therapeutic agent against *Helicobacter pylori.* Cureus. 2018; 10: e3062.
96. Chambial S, Dwivedi S, Shukla KK, John PJ, Sharma P. Vitamin C in disease prevention and cure: an overview. Indian J Clin Biochem. 2013; 28: 314-28.
97. Zhang MM, Qian W, Qin YY, He J, Zhou YH. Probiotics in *Helicobacter pylori* eradication therapy: a systematic review and meta-analysis. World J Gastroenterol. 2015; 21: 4345-57.
98. Wang KY, Li SN, Liu CS, Perng DS, Su YC, Wu DC, et al. Effects of ingesting *Lactobacillus* -and *Bifidobacterium* -containing yogurt in subjects with colonized *Helicobacter pylori*. The American Journal of Clinical Nutrition. 2004; 80: 737-41.
99. Tongtawee T, Dechsukhum C, Leeanansaksiri W, Kaewpitoon S, Kaewpitoon N, Loyd RA, et al. Improved *Helicobacter pylori* eradication rate of tailored triple therapy by adding *Lactobacillus delbrueckii* and *Streptococcus thermophilus* in Northeast Region of Thailand: a prospective randomized controlled clinical trial. Gastroenterol Res Pract. 2015; 2015: 518018.
100. Gotteland M, Brunser O, Cruchet S. Systematic review: are probiotics useful in controlling gastric colonization by *Helicobacter pylori*? Aliment Pharmacol Ther. 2006; 23: 1077-86.
101. Kuo CH, Wang SS, Lu CY, Hu HM, Kuo FC, Weng BC, et al. Long-term use of probiotic-containing yogurts is a safe way to prevent *Helicobacter pylori:* based on a Mongolian gerbil's model. Biochem Res Int. 2013; 2013: 594561.
102. Ji J, Yang H. Using probiotics as supplementation for *Helicobacter pylori* antibiotic therapy. Int J Mol Sci. 2020; 21: 1136.