Review of foodborne helicobacteriosis

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Abstract

Helicobacteriosis is a common bacterial infection caused by *Helicobacter pylori*. It affects the stomach and small intestines, leading to inflammation. Bacteria can spread through contaminated food or water. This review explores the role of food in the transmission of *H. pylori*, drawing on research from the past three decades. People commonly acquire the infection during childhood, often from close family members. Crowded living conditions can also contribute to the spread. This review also discusses various risk factors and highlights the challenges of detecting *H. pylori*, particularly in its dormant form. Techniques like ribotyping and restriction fragment length polymorphism hold promise for tracing transmission routes, but more long-term studies are needed to account for potential confounding factors.

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Introduction

Helicobacteriosis, the infection caused by *Helicobacter pylori*, is recognized as the most prevalent human infection worldwide (Shaaban *et al*., 2023). Its incidence is notably higher in regions characterized by poor hygiene and low economic status, resulting in higher rates of infection in Africa, South America, and Asia in comparison to Western Europe, North America, and Australia (Tonkic *et al*., 2012; Hooi *et al*., 2017; Bashir and Khan, 2023). The prevalence of *H. pylori* infection is influenced by various factors, including living conditions, dietary habits, and geographic location (Sjomina *et al*., 2018; Al-Mashhadany, 2020). Infected individuals serve as the primary reservoir for *H. pylori*, facilitating transmission of the infection to others since most infections are asymptomatic (Denic *et al*., 2020).

The belief that the human stomach was sterile and unsuitable for microorganisms due to its highly acidic conditions changed decades ago. In 1982, H. *pylori* bacteria were successfully isolated from gastric biopsies by Marshall and Warren, demonstrating their ability to survive in patients with active chronic gastritis, gastric ulcers, or duodenal ulcers (Elbehiry *et al*., 2023). *H. pylori* is now classified by the World Health Organization as a group 1 carcinogen and the causative agent of gastric diseases, including gastritis, ulcers, and gastric cancer (Al-Mashhadany *et al*.,2018; Denic *et al*., 2020). It is estimated that approximately half of the global population is infected with *H. pylori* (Denic *et al*., 2020; Qasim *et al*., 2023). New *H. pylori* infections are believed to result from direct human-to-human transmission, which can occur through oral-oral or fecal-oral routes or both. The presence of bacteria has been detected in various bodily fluids, including stool, saliva, vomitus, and gastric refluxate (Mégraud *et al.*, 2007). Typically, the infection occurs during early childhood and is often transmitted by close family members. Premastication of food by a parent has been suggested as a potential risk factor for *H. pylori* transmission; however, the certainty of this association remains uncertain, and further evidence is needed. Additionally, a higher prevalence of *H. pylori* has been positively associated with crowding during childhood, both within and outside the family (Almashhadany *et al*., 2023). Other potential sources of transmission include contaminated water and food (Aziz *et al.*, 2015).

There are several methods for detecting *H. pylori* in human clinical specimens (Sabbagh *et al.*, 2018; Godbole *et al*., 2020). These methods can be broadly categorized as invasive or non-invasive. Invasive methods require endoscopy with biopsies of gastric tissues for histology, culture, and rapid urease testing. Non-invasive tests include the urea breath test and fecal antigen tests, which are quick diagnostic procedures with comparable accuracy to biopsy-based techniques and are the methods of choice in the test and treatment setting (Sabbagh *et al*., 2018). Serological methods to detect immunoglobulin G antibodies to *H. pylori* can also show as high accuracy as other non-invasive and invasive biopsies but do not differentiate between current or past *H. pylori* infections (Cardos *et al*., 2022). Polymerase chain reaction (PCR) is an emerging option that can be categorized as both invasive and non-invasive tests. The PCR approach is beneficial for detecting *H. pylori* from gastric biopsies without the need for cultures (Sohrabi *et al*., 2021).

Due to its fastidious growth requirements and ability to enter a viable but nonculturable state under stressful conditions, the detection of *H. pylori* in food and water can be challenging. Consequently, molecular methods that rely on the identification of *H. pylori*-specific DNA or RNA sequences are commonly employed to assess the presence of *H. pylori* in food and water samples. Numerous epidemiological studies have highlighted drinking water sources as a significant risk factor for *H. pylori* infection (Quaglia *et al.*, 2008; Al-Mashhadany and Mayass, 2017; Durazzo *et al*., 2021).

H. pylori has been detected in drinking water, seawater, vegetables, and foods of animal origin. It can survive in complex foodstuffs such as milk, vegetables, and ready-to-eat foods. In general, the survival of *H. pylori* is better in filtered water than in autoclaved water. It has been reported that *H. pylori* can survive several days in water at 5°C, supporting the observation that *H. pylori* survive better at 5°C than at higher temperatures (Quaglia and Dambrosio, 2018). Certainly, detecting *H. pylori* in food and water is crucial for preventing its transmission and potential health risks. There are several diagnostic methods available for detecting *H. pylori* infections, all of which can be broadly classified as either invasive or non-invasive. Invasive methods necessitate upper endoscopy and the analysis of gastric biopsy samples. If the patient necessitates upper endoscopy, various diagnostic approaches can be employed to diagnose *H. pylori* infection, including histological analysis, rapid urease testing, molecular methods, or culture. Non-invasive testing options encompass immunological methods such as serology and stool antigen testing, as well as the 13C-urea breath test and molecular methods. Preferential consideration should be given to non-invasive diagnostic techniques (Bessède *et al*., 2017; Bordin *et al*., 2021). This review aimed to address *H. pylori* infection in terms of its epidemiology and potential transmission by food and water. The preventive measures at the personal and community levels were discussed.

Taxonomy and pathogenic *Helicobacter* species

The *Helicobacteraceae* family consists of gram-negative, spiral-shaped bacteria known for their helical or curved morphology. The family *Helicobacteraceae*, which lies within the Epsilon subdivision of the Proteobacteria, consists of five *Helicobacter* genera: *Sulfuricurvum*, *Sulfurimonas*, *Sulfurovum*, *Thiovulum*, and *Wolinella* (Mitchell *et al.*, 2014; Garrity *et al.*, 2015). This family is dominated by the *Helicobacter* genus, which currently consists of 33 validated named species and several candidates and unclassified organisms (Mitchell *et al.*, 2014). *Helicobacter* is the representative genus and *H. pylori* is the type species of this family (Taillieu *et al*., 2022). Species belonging to *Helicobacter* and *Wolinella* are commonly associated with animal and/or human hosts and typically colonize the oral and gastrointestinal tracts (Varon *et al.*, 2022).

The *Helicobacter* genus is commonly classified into two groups: gastric and enterohepatic (non-gastric) species (Romo-Gonzalez *et al*., 2022). These groups exhibit a high level of organ specificity, with gastric helicobacters typically unable to colonize the intestine or liver, and *vice versa*. Gastric species are known to colonize the stomachs of humans and a wide range of animals, including cattle, sheep, goats, dogs, cats, cheetahs, rhesus monkeys, ferrets, whales, and dolphins (On *et al.*, 2015). This group includes *H. pylori*, *H. felis*, *H. mustelae*, *H. acinonychis*, and *H. heilmannii*. *H. acinonychis* is associated with chronic gastritis and ulceration in big cats, such as cheetahs and tigers, and is a common cause of death in cheetahs (On *et al*., 2015). In humans, *H. heilmannii* infection can lead to gastritis and dyspeptic symptoms, and in rare cases, even ulcer disease. However, the inflammation is typically less severe compared to individuals infected with *H. pylori* (Husnik *et al*., 2022).

Enterohepatic species of the *Helicobacter* genus colonize the lower gastrointestinal tract, including the biliary tree, in humans and other mammals. These persistent infections are associated with chronic inflammation and hyperproliferation of epithelial cells, which can lead to neoplastic and hepatobiliary diseases in humans (Verhoef *et al*., 2003). There are nineteen named non-gastric *Helicobacter* species that colonize the lower intestinal tract of animals, many of which can also colonize humans. These species include *H. canadensis*, H. *rodentium*, *H. pullorum*, *H. fennelliae*, *H. trogontum*, *H. muridarum*, *H. hepaticus*, *H. canis*, *H. bilis*, *H. rappini*, *H. cinaedi*, *H. westmeadii*, *H. pametensis*, *H. winghamensis*, *H. mesocricatorum*, *H. aurati*, *H. typhlonius*, *H. cholecystus*, and *H. trogontum* (On *et al*., 2015; Romo-Gonzalez *et al*., 2022). These *Helicobacter* species naturally colonize the intestinal crypts and are often associated with diarrhea. They can also cause bacteremia and systemic disease, including cholecystitis, colonization of the biliary tract, hepatitis, and in some cases, hepatic cancer. Eight of these enterohepatic *Helicobacter* species (*H. canis*, *H. pullorum*, *H. cinaedi*, *H. fennelliae*, *H. canadensis*, *H. winghamensis*, *H. westmeadii*, and *H. rappini*) have been isolated from humans with diarrhea and/or bacteremia (Garrity *et al*., 2015; On *et al*., 2015; Husnik *et al*., 2022).

Bacteriology of *Helicobacter pylori*

H. pylori is a microaerophilic, gram-negative bacterium with an average length ranging from 0.5 to 5 μm and a tuft of 5 to 7 polar sheathed flagella, each approximately 3 μm in length. The helical or curved rod shape of *H. pylori* enables it to move through the mucus lining of the stomach. The ability of *H. pylori* to live, swim, grow, and move within the acidic environment of the stomach is facilitated by its shape, size, and flagellation (On *et al*., 2015).

The complex cell wall structure of *H. pylori*, similar to that of other gram-negative bacteria, comprises an outer membrane, a thin peptidoglycan layer, and an inner cytoplasmic membrane. The presence of a capsule, a slimy layer outside the cell wall, may or may not be observed in *H. pylori*. Under specific circumstances, such as exposure to antibiotics or harsh environments, a morphological transformation from the characteristic spiral shape to coccoid forms can occur in *H. pylori*. It is noteworthy that the morphology of *H. pylori* is subject to variation and can adapt to its surroundings and growth conditions. Additionally, the species exhibits a high degree of diversity, leading to potential differences in morphology among various strains (On *et al*., 2015; Al-Mashhadany, 2018).

Epidemiology

In 2015, a total of 4.4 billion cases of *H. pylori* were estimated *via* a meta-analysis of epidemiological surveys (Hooi *et al*., 2017; Bashir and Khan, 2023). A higher prevalence of *H. pylori* is observed in unsanitary and economically poor regions, particularly in Asia, Africa, and South America, compared to regions such as Australia, North America, and Western Europe (Sjomina *et al*., 2018; Al-Mashhadany, 2020; Almashhadany *et al*., 2022; Balas *et al*., 2022). It is worth noting that a significant proportion of infected individuals remain asymptomatic, serving as potential carriers and unknowingly transmitting the infection to others (Denic *et al*., 2020).

The geographical variation of *H. pylori* frequency has been documented with over 80% of the population in certain developing countries being positive for *H. pylori*, while the prevalence in industrialized countries generally remains below 40% (Sjomina *et al*., 2018). Moreover, the prevalence of *H. pylori* tends to be lower in children and adolescents compared to adults and elderly individuals (Al-Moayad, 2012). In terms of regional distribution, developing countries exhibit an occurrence below 50%, whereas developed countries have a prevalence rate of around 35% (Zamani *et al*., 2018). Specifically, the prevalence of *H. pylori* is 63.5% in India, 81.0% in Pakistan, 77.2% in Western Asia, and 70.1% in Africa (Khoder *et al*., 2019). In contrast, the frequency of *H. pylori* in North America is approximately 20-30%, while in the United States of America, it ranges from 30-40% (Willems *et al.*, 2020).

The relationship between *H. pylori* infection and certain living habits remains uncertain. However, studies have shown that the infection rate of *H. pylori* is lower in the elderly who have higher education, engage in significant mental work, or reside in more economically developed regions (Nurgalieva *et al*., 2002; Matsuhisa *et al*., 2015). In an early epidemiological survey conducted in Beijing, China, the prevalence of *H. pylori* infection among the elderly was reported to be 83.4% (Zhang *et al*., 2005). However, a recent investigation found a lower rate of 46.5%, with males exhibiting a higher infection rate than females (51.8% *versus* 42.5%), and an increase in infection rate with age (Zhu *et al*., 2020). Previous studies have also examined the infection rate of *H. pylori* in the elderly with peptic ulcer disease. These studies reported infection rates ranging from 58% to 78%. However, it is worth noting that only 40% to 56% of these individuals were tested for *H. pylori* infection, and among those with a positive test, only 50% to 73% received antibiotic treatment (Pilotto and Franceschi, 2014). Furthermore, there is evidence suggesting a decreasing trend in *H. pylori* infection rates among both adults and children in certain countries (Bureš *et al*., 2012; Tonkic *et al*., 2012).

Transmission of *Helicobacter pylori*

The transmission dynamics of *H. pylori* are crucial to understand for effective prevention and control strategies. The precise mechanism of transmission remains poorly understood. It is postulated that the bacterium can be transmitted either directly from person to person, as the primary route, or indirectly from the environment to individuals (Zamani *et al*., 2018; Almashhadany *et al*., 2022). Person-to-person transmission is considered to be the primary mode of transmission, particularly in developed countries. However, in developing countries with inadequate sanitation, transmission through contaminated food and water is likely to occur, leading to a more rapid spread of *H. pylori* (Vale and Vítor, 2010; Zamani *et al*., 2017; Al Mashhadany and Mayass, 2018). Not all individuals exposed to *H. pylori* will manifest symptoms or experience complications. Other factors, such as the host immune response, individual susceptibility, and bacterial strain, significantly influence the outcome of the infection (Sukri *et al*., 2020). However, Figure 1 illustrates the transmission routes of *H. pylori* to humans.

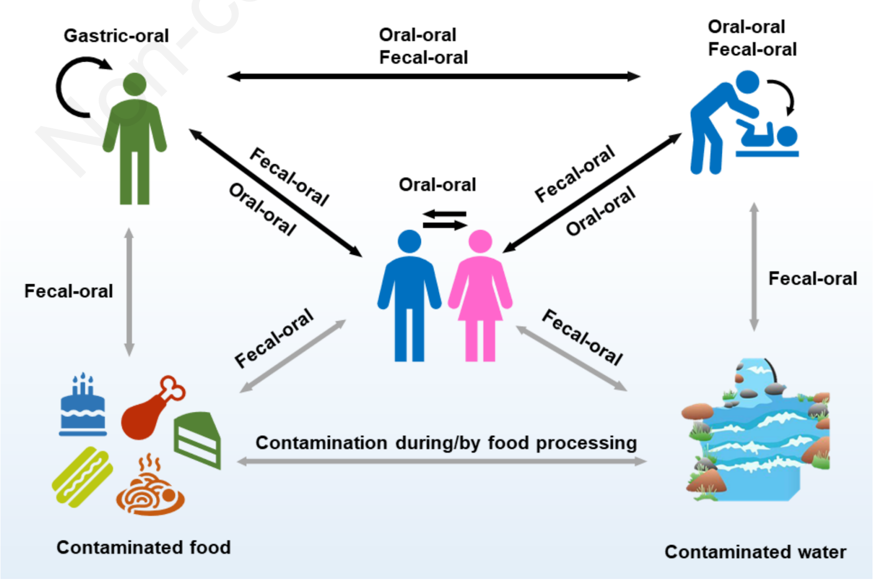

Figure 1. Transmission of *Helicobacter pylori.* Transmission routes with direct evidence are drawn in black arrows, while gray arrows indicate suspected transmission as evidenced only by the detection of bacteria or its DNA in non-human samples. Oral-oral transmission can occur during the sharing of food utensils or between mothers and their newborns.

Oral-oral transmission

H. pylori is primarily considered a gastric organism; however, research has indicated that infected individuals may harbor *H. pylori* in their mouth and saliva, either on a permanent or transient basis. The transmission of *H. pylori* through oral-oral routes can occur when the bacterium is directly transmitted to another individual *via* activities such as kissing, sharing utensils, or engaging in close personal contact (Wang *et al*., 2019). The oral cavity has been identified as a reservoir for microorganisms, including *H. pylori*, as demonstrated by Miyabayashi *et al.* (2000), who found that the presence of *H. pylori* in the oral cavity constitutes a risk factor for recurrent gastric infection. Additionally, it has been recommended that adjunctive periodontal treatment enhances the efficacy of *H. pylori* therapy and reduces the recurrence of gastric infection (Tongtawee *et al.*, 2019).

Gastro-oral and fecal transmission

The transmission of *H. pylori* from the gastrointestinal tract to the oral cavity is referred to as the gastro-oral route. This route is facilitated by the presence of the bacterium in the stomach and duodenum, and through mechanisms such as regurgitation or vomiting, the bacteria can be transferred to the mouth and potentially disseminated to others through oral contact. Both oral-oral and gastro-oral routes play a role in the transmission of *H. pylori* and significantly contribute to its prevalence among individuals (Zamani *et al*., 2017; Mezmale *et al*., 2020).

The presence of *H. pylori* in the feces of infected individuals has been documented (Tonkic *et al*., 2012; Godbole *et al*., 2020). Transmission through the fecal-oral route can occur when contaminated fingers come into contact with shared food or food utensils. Such contamination is often associated with poor sanitation or improper food handling practices, particularly in regions where inadequate hygiene practices are prevalent (Kayali *et al*., 2018).

Sexual routes

It has been indicated by several studies that non-gut organs such as the vagina, ears, and nasopharyngeal sinus cavities can be inhabited by *H. pylori* (Eslick, 2000; Dimitriadi, 2014; Shishegar *et al*., 2015;). The transmission of *H. pylori* through sexual contact has been observed, with the vagina potentially serving as a reservoir for the bacterium, either permanently or temporarily (Eslick, 2000; Dimitriadi, 2014). Studies have demonstrated that when one partner in a sexual relationship is infected with *H. pylori*, the non-infected partner faces an increased risk of acquiring the infection. *H. pylori* can colonize yeast in the vagina and has been associated with the formation of biofilms, which can contribute to treatment-resistant bacterial vaginosis (Sánchez-Alonzo *et al*., 2021). Vaginal yeasts are more favorable to *H. pylori* colonization compared to oral yeasts, which facilitate transmission to infants during vaginal delivery.

Risk factors

Several risk factors contribute to an increased likelihood of acquiring *H. pylori* infection (Balas *et al*., 2022; Bashir and Khan, 2023). It is noteworthy that many of these risk factors can be avoided through the acquisition of adequate knowledge and the implementation of appropriate practices. The general community appears to lack adequate knowledge regarding *H. pylori*, particularly regarding its mode of transmission (Hafiz *et al*., 2021). However, a study conducted by Alaridah *et al.* (2023) revealed the presence of misconceptions and highlighted the need for further expansion and support in knowledge dissemination concerning *H. pylori*.

Personal hygiene and socioeconomic status

The probability of acquiring *H. pylori* infection can be increased by poor hygiene practices, including inadequate handwashing, particularly after using the restroom or before eating (Che *et al*., 2023). A higher risk of *H. pylori* infection has been associated with lower socioeconomic status, potentially attributable to factors such as inadequate sanitation, limited healthcare access, and suboptimal living conditions (Balas *et al*., 2022; Meliț *et al*., 2022).

Living in crowded or unsanitary conditions

In regions characterized by overcrowded living conditions or limited access to hygienic water and proper sanitation, the prevalence of *H. pylori* infection is further amplified. These findings underscore the importance of the fecal-oral route and the influence of crowded living conditions in facilitating the transmission of *H. pylori* (Bashir and Khan, 2023). Consequently, the implementation of preventive protocols should prioritize the dissemination of instructions about sanitation practices, especially in densely populated areas (Che *et al*., 2023).

Close contact with diseased people

Transmission of *H. pylori* infection within families is facilitated by intrafamilial frequent contacts, particularly in cases of repeated exposure to the same infected individuals (Khoder *et al*., 2019). The bacteria are known to be transmitted through person-to-person contact, with childhood being the typical transmission period. Acquisition of this infection predominantly occurs during infancy or childhood, with close person-to-person contact serving as the primary route of transmission (Balas *et al*., 2022). Notably, the prevalence of *H. pylori* within the same household increases progressively with age, ranging from 10% to 30% in adolescents to 40% to 60% in the elderly (Kayali *et al*., 2018).

Consumption of contaminated food or water

While direct evidence is insufficient to definitively establish the role of food products in the environmental transmission of *H. pylori*, numerous studies have successfully isolated *H. pylori* or identified its DNA in samples of food and water. Consequently, the consumption of improperly prepared food contaminated with *H. pylori* can potentially result in infection. Additionally, regions characterized by limited access to clean water may be associated with an elevated risk of *H. pylori* infection (Bashir and Khan, 2023; Che *et al*., 2023). The bacterium *Helicobacter* pylori has been studied as a potential foodborne pathogen, particularly in relation to its spread through contaminated meat products (Akhlaghi *et al*., 2024). While researchers have explored this possibility, the degree to which *H. pylori* transmission *via* meat contributes to overall infection rates remains an area of ongoing investigation.

Age

In developing countries, the acquisition of *H. pylori* infection at a younger age is attributed to close contact with infected individuals, including family members, and unless treated, it typically persists as a lifelong infection in most individuals. The infection is commonly acquired by children before reaching 10 years of age

(Balas *et al*., 2022). Conversely, in developed countries, the prevalence of infection among children is lower. However, the infection rate increases with age, and by the time individuals reach 60 years of age, approximately 50% of the population is infected (Venero-Fernández *et al*., 2020).

Smoking

A significant association between cigarette smoking and residing in the same household as *H. pylori*-positive families was observed in *H. pylori* positivity (Monno *et al*., 2019). Additionally, Itskoviz *et al.* (2017) reported that smoking was found to significantly elevate the likelihood of ineffective first-line treatment for *H. pylori* infection.

Role of food and water in transmission

The role of food in the transmission of *H. pylori* has been investigated, with milk, meat, and vegetables being the most commonly analyzed food products (Vale and Vítor, 2010). Among these, milk products have received the most attention, likely because *H. pylori* infection is primarily acquired during childhood when milk is a common dietary component (Vale and Vítor, 2010). However, individuals who consume raw vegetables have been found to have a higher likelihood of acquiring *H. pylori* (Zamani *et al*., 2017). This association between *H. pylori* infection and the consumption of raw vegetables indirectly suggests that the bacterium may be present in the water used for irrigating these vegetables (Aziz *et al*., 2015; Zamani *et al*., 2017). It is important to acknowledge the challenges in determining the exact modes of transmission, as *H. pylori* is difficult to culture from environmental samples, and association does not necessarily imply causation (Almashhadany *et al*., 2022).

Previous studies have examined the survival of *H. pylori* by testing various samples such as water, meat, seafood, vegetables, and milk (Guner *et al*., 2011; Quaglia et al., 2007; Quaglia *et al*., 2020). For example, Quaglia *et al.* (2007) conducted a study where artificially contaminated pasteurized and ultrahigh temperature (UHT) milk samples were stored aerobically at 4°C. The results showed that the bacterial load progressively decreased, with a median survival of 9 days in pasteurized milk and 12 days in UHT milk. The initial inoculum was approximately 105 and 106 CFU/mL for pasteurized and UHT milk, respectively. In contrast, it was found that *H. pylori* did not grow at refrigeration temperature on vegetable substrates but remained viable and culturable for up to 5 days at 20°C (Pina-Pérez *et al*., 2018).

Consumption of contaminated food

H. pylori infections can potentially originate from food sources (Vale and Vítor, 2010). However, the fastidious growth requirements of this species, coupled with its ability to enter a viable but nonculturable state under stressful conditions, pose challenges in isolating *H. pylori* from various food samples. Consequently, molecular methods that rely on the detection of *H. pylori*-specific DNA or RNA sequences are frequently employed to assess the presence of *H. pylori* in food (Meng *et al*., 2008; Quaglia *et al*., 2008; Almashhadany *et al.*, 2022). *H. pylori* was found in human and animal samples. Additionally, *glmM* was discovered in both milk and human samples. The findings by Shaaban *et al*. (2023) imply that domestic and agricultural animals may transfer *H. pylori* infection to people.

Drinking of contaminated water

A positive association between the prevalence of *H. pylori* infection and untreated or fecally contaminated drinking water has been reported in several epidemiological studies (Mezmale *et al*., 2020). Families utilizing non-flush toilets, outdoor toilets, outdoor water taps, and river water have been found to have a higher prevalence of *H. pylori* infection. These findings suggest that an increased frequency of microorganisms is positively associated with poor hygiene. The survival of *H. pylori* in water can extend for several weeks, with factors such as temperature, salt content, and nutrient levels influencing its persistence (Aziz *et al*., 2015).

Using contaminated kitchen instruments

Sharing plates, glasses, and other utensils with an individual infected with *H. pylori* can potentially lead to transmission. The bacteria can survive on these surfaces and be transferred to another individual if proper cleaning and disinfection are not followed (Mezmale *et al*., 2020; She *et al*., 2023) (Table 1) (Dore *et al*., 1999; Stevenson *et al*., 2000; Dore *et al*., 2001; Fujimura *et al*., 2002; Turutoglu and Mudul, 2002; Quaglia *et al*., 2008; Meng *et al*., 2008; Angelidis *et al*., 2011; Safaei *et al*., 2011; Rahimi and Kheirabadi, 2012; Momtaz *et al*., 2014; Mousavi *et al*., 2014; Atapoor *et al*., 2014; Yahaghi *et al*., 2014; Esmaeiligoudarzi *et al*., 2015; Talaei *et al*., 2015; Bianchini *et al*., 2015; Osman *et al*., 2015; Abdel-Latif *et al*., 2016; Saeidi and Sheikhshahrokh, 2016; Hemmatinezhad *et al*., 2016; Ghorbani *et al*., 2016; Eldairouty *et al*., 2016; Gilani *et al*., 2017; Al-Mashhadany and Mayass, 2017; Khaji *et al*., 2017; Talimkhani and Mashak, 2017; Ranjbar *et al*., 2018; Hamada *et al*., 2018; Elhariri *et al.,* 2018; Guessoum *et al*., 2018; Mashak *et al*., 2020; Kareem and Maaly, 2021; Elrais *et al*., 2022; Al-Shrief and Thabet, 2022; Almashhadany *et al*., 2022; Asadi *et al*., 2023; Shaaban *et al*., 2023; Piri-Gharaghie *et al*., 2023).

Signs and symptoms of helicobacteriosis

Several individuals infected with *H. pylori* may not show any symptoms, but the infection can lead to different gastrointestinal diseases and complications (Pina Dore *et al*., 2022). It is important to note that these symptoms can also be associated with other gastrointestinal conditions, so a proper diagnosis by a healthcare professional is essential.

H. pylori infection is primarily associated with abdominal pain, which is often described as a burning or distressing sensation (Marzio *et al*., 2003). The pain is typically felt in the upper abdomen and worsens when fasting, with nocturnal episodes being common. Nausea is a common symptom experienced by certain individuals, and in some cases, it may progress to vomiting with the presence of coffee ground-like or blood-tinged material. The infection can also lead to abdominal distension, bloating, and frequent burping owing to increased gas production. Even without visible distention, individuals may experience a subjective feeling of a bloated stomach. The black, tarry stool is a characteristic sign of *H. pylori* gastritis. Some individuals may also experience heartburn and acid reflux, with a burning sensation in the chest, which can be chronic or intermittent (Ceylan *et al.*, 2007; Al Mashhadany and Mayass, 2018; Mărginean *et al*., 2022).

H. pylori infection has been linked to halitosis, a malodor characterized by a foul odor due to elevated levels of hydrogen sulfide due to the putrefactive action of *H. pylori*. The infection may also increase the risk of erosive changes in the stomach, potentially leading to the production of volatile sulfur compounds (Pina Dore *et al*., 2022). In cases where *H. pylori* infection causes stomach bleeding, the presence of black, tarry stools may indicate the presence of blood (Bashir and Khan, 2023).

Chronic *H. pylori* infection can lead to continuous stomach bleeding, potentially causing iron deficiency anemia. It may also result in decreased appetite due to discomfort and chronic inflammation, which can contribute to weight loss. The infection can cause a general feeling of weakness and fatigue. Patients may also experience fatigue and a sensation of fullness even after eating a small amount of food (Pina Dore *et al*., 2022).

Prevention and control of helicobacteriosis

Prevention of *H. pylori* infection can be achieved through various techniques. The most effective measure is to avoid the risk factors associated with *H. pylori* infection and practice good hygiene. However, it is important to note that these preventive measures may help reduce the risk of infection, but they are not guaranteed to be completely effective.

Personal hygiene

Practicing good sanitation, including regular handwashing, is crucial in preventing the transmission of *H. pylori*. Since bacteria can be spread through contaminated hands, it is important to wash hands thoroughly with soap and water after using the restroom, before eating, and after contact with potentially contaminated surfaces (Mezmale *et al*., 2020). When traveling, especially to areas with lower hygiene standards, it is important to be extra cautious about food safety, handwashing, and avoiding contaminated water sources to reduce the risk of *H. pylori* infection and other infectious diseases (Yin *et al*., 2009; Almashhadany, 2019, 2020, 2021).

Table 1. Studies that detected *Helicobacter pylori* in different food types.

Year	Country	Detection method	Food type	Reference
1999	Italy	PCR	Sheep milk	Dore *et al*., 1999
2000	USA	Culture	Retail beef	Stevenson *et al*., 2000
2001	Italy	Culture & PCR	Sheep milk and gastric tissue	Dore *et al*., 2001
2002	Japan	PCR, culture, EM	Raw and pasteurized cow milk	Fujimura *et al*., 2002
	Turkey	Culture	Raw sheep milk	Turutoglu and Mudul, 2002
2008	Italy	Nested-PCR	Raw goat, sheep, and cow milk	Quaglia *et al*., 2008
	USA	Multiplex PCR	Raw chicken and ready-to-eat raw tuna	Meng *et al*., 2008
2011	Greece	FISH	Raw cow milk	Angelidis *et al*., 2011
	Iran	ELISA & PCR.	Cow's milk	Safaei *et al*., 2011
2012	Iran	PCR	Raw milk from cows, sheep, goats, buffalo and camel	Rahimi and Kheirabadi, 2012
2014	Iran	PCR	Rumen (cow, sheep, and goat) in slaughterhouse	Momtaz *et al*., 2014
	Iran	Culture & PCR	Milk and traditional dairy products	Mousavi *et al*., 2014
	Iran	Culture & PCR	Vegetables and salad	Atapoor *et al*., 2014
	Iran	Culture & PCR	Washed and unwashed vegetables	Yahaghi *et al*., 2014
2015	Iran	Culture & PCR	Milk and dairy products	Esmaeiligoudarzi *et al*., 2015
	Iran	PCR	Raw cow, sheep, goat, buffalo, and, camel milk	Talaei *et al*., 2015
	Italy	Culture &PCR	Bulk tank milk of dairy cattle	Bianchini *et al*., 2015
	Sudan	Culture &PCR	Raw cow milk	Osman *et al*., 2015
2016	Egypt	PCR	Cow's milk	Abdel-Latif *et al*., 2016
	Iran	Culture & PCR	Raw cow, sheep, goat, buffalo, and camel milk and meats	Saeidi and Sheikhshahrokh, 2016
	Iran	Culture & PCR	Ready-to-eat food	Hemmatinezhad *et al*., 2016
	Iran	PCR	Fish, ham, chicken, vegetable, meat sandwiches, minced meat	Ghorbani *et al*., 2016
	Egypt	Culture	Raw meat, raw poultry meat, and luncheon meat samples,	Eldairouty *et al*., 2016
2017	Iran	Culture & PCR	Hamburger and minced meat	Gilani *et al*., 2017
	Yemen	Culture	Red meat, poultry meat, salad	Al-Mashhadany and Mayass, 2017
	Iran	PCR	Milk and dairy samples	Khaji *et al*., 2017
	Iran	Culture & PCR	Meat, milk, and vegetables	Talimkhani and Mashak, 2017
2018	Iran	PCR	Raw milk	Ranjbar *et al*., 2018
	Egypt	PCR	Chicken samples	Hamada *et al*., 2018
	Egypt	PCR	Cows, buffaloes, and sheep milk	Elhariri *et al*., 2018
	Algeria	ELISA & PCR	Milk	Guessoum *et al*., 2018
2020	Iran	PCR	Raw meat	Mashak *et al*., 2020
2021	Iraq	PCR	Meat samples	Kareem and Maaly, 2021
2022	Egypt	PCR	Chicken meat, swabs	Elrais *et al*., 2022
	Egypt	Culture & PCR	Cows' milk	Al-Shrief and Thabet, 2022
	Yemen	Culture	Chicken meat	Almashhadany *et al*., 2022
2023	Iran	PCR	Raw poultry meat	Asadi *et al*., 2023
	Iran	PCR	Animal milk samples	Shaaban *et al*., 2023
	Iran	Culture & PCR	Raw poultry meat	Piri-Gharaghie *et al*., 2023

EM, electron microscopy, FISH, fluorescence *in situ* hybridization; PCR, polymerase chain reaction; ELISA, enzyme-linked immunosorbent assay.

Water and food safety

Practicing good water and food safety techniques is crucial. *H. pylori* can be transmitted through contaminated water and food if they are not prepared and handled properly (She *et al*., 2023). To prevent *H. pylori* infection, it is important to ensure that drinking water comes from a reliable source and is safe for consumption. Moreover, consuming properly cooked food and avoiding the consumption of raw or undercooked shellfish and meat also reduces the likelihood of infection. It is also important to wash vegetables and fruits thoroughly, as they can be a potential source of *H. pylori* infection. Additionally, it is worth noting that post-processed contaminated milk may have a higher risk of transmitting *H. pylori* due to its ability to survive for up to a week (Quaglia *et al*., 2007).

Avoiding close contact with infected individuals

To prevent the transmission of the infection, it is imperative to exercise caution and refrain from close contact with individuals within one's household or immediate social circle who have been diagnosed with *H. pylori*. This is because *H. pylori* can be transmitted through saliva and vomit. Consequently, it is advisable to abstain from sharing personal items, such as utensils, drinking glasses, and other belongings, with individuals who may be infected or have a history of *H. pylori* infection (Sjomina *et al*., 2018; Mezmale *et al*., 2020).

Awareness of the infection

Acquiring knowledge regarding the risk factors, symptoms, and modes of transmission of *H. pylori* is crucial for individuals to safeguard themselves and make informed decisions. Patient education serves as a cost-effective, safe, and convenient approach in this regard. In a recent study, it was suggested that implementing enhanced educational interventions led to positive outcomes in terms of both the eradication rate of *H. pylori* and the adherence of infected patients to treatment regimens (Zha *et al.*, 2022). Zhou *et al.* (2022) observed that efforts to address risk factors at not only the individual level but also within the family and school environments were crucial in advancing knowledge, attitudes, and practices among children, family members, and teachers, thereby fostering a healthier society. Consequently, such interventions would serve as valuable complements to clinical treatment programs.

Maintaining a clean environment

The preservation of a clean environment is deemed necessary for the promotion of overall health and serves as a fundamental measure in preventing the transmission of various infectious pathogens, including *H. pylori*. Nevertheless, the prevention of *H. pylori* infection can be achieved through the modification of lifestyles and behaviors, as well as the enhancement of environmental sanitation through hygiene interventions targeted towards vulnerable populations (Sjomina *et al*., 2018; Mezmale *et al*., 2020).

Rational administration of medications

When taking non-steroidal anti-inflammatory drugs (NSAIDs), it is vital to be cautious and utilize these drugs at the lowest effective dosage and for the shortest duration possible. This is due to the potential of NSAIDs to induce irritation of the stomach lining and increase the likelihood of peptic ulcer progression, thereby facilitating *H. pylori* infection (Alexander *et al*., 2021). Moreover, the unnecessary and excessive use of antibiotics has the potential to disrupt the normal balance of gut flora, potentially encouraging the proliferation of *H. pylori*. Therefore, it is advised to only take antibiotics when necessary.

Quitting smoking and alcohol

Smoking can irritate and damage the stomach lining, making it easier for *H. pylori* to colonize and cause complications, so the improvement of stomach lining health by quitting smoking allows the stomach lining to heal and decreases the risk of additional problems (Wu *et al*., 2020). Furthermore, excessive alcohol consumption can irritate the stomach lining, necessitating the limitation of alcohol intake to promote optimal digestive health.

Role of probiotics in preventing *Helicobacter pylori*

Probiotics are live microbes that can provide health benefits when consumed in specific quantities. They are known for their positive effects on gut health and have been studied for their potential role in managing several gastrointestinal disorders, including *H. pylori* infection. Some studies suggest that certain probiotics may help inhibit the growth of *H. pylori* and promote a healthy balance of gut microbiota (Zhang *et al*., 2015). Other studies have investigated the potential benefits of using probiotics in combination with standard antibiotic treatments for *H. pylori* eradication. However, research on the role of probiotics in treating or preventing *H. pylori* infection is still ongoing (Keikha and Karbalaei, 2021).

Regular screening and treatment

Screening tests are of paramount importance, especially in cases where a family history of *H. pylori* infection or when gastrointestinal symptoms are suspected. It is worth emphasizing that early detection plays a pivotal role in facilitating prompt treatment. However, cross-sectional studies revealed that only a limited number of participants had undergone a screening test for *H. pylori*, with the majority possessing minimal knowledge regarding this infection (Wang *et al*., 2019; Teng *et al*., 2021). Lastly, studies have demonstrated that *H. pylori* vaccines have proven ineffective in reducing microbial load and have only provided limited immunity (Stubljar *et al*., 2018). Vaccination holds promise as a preventive measure against *H. pylori* infection on a global scale. However, previous attempts to develop an *H. pylori* vaccine have yielded disappointing results (Li *et al*., 2023). While certain vaccine candidates have shown potential for prophylactic use, none have demonstrated clinical applicability (Zhang *et al*., 2022).

Conclusions

Concerns about *H. pylori* are widespread due to its problematic nature as a pathogen that infects more than the world population. The stomach lining is commonly infected by *H. pylori*, which can cause gastritis, peptic ulcers, and other gastrointestinal manifestations. Person-to-person transmission is thought to occur through oral-oral, fecal-oral, gastric-oral, or sexual routes. Two routes of transmission exist: i) direct routes (oral-oral, gastro-oral, fecal-oral, and sexual routes); and ii) indirect routes (drinking of contaminated water, consumption of contaminated food, and using contaminated utensils). Although *H. pylori* is unlikely to grow in food, it may survive in a viable but nonculturable form. This might lead to an underestimation of its prevalence in food and water. It is not clear how the conversion from a viable nonculturable state to a viable state occurs. This remains to be resolved, particularly since it is not known whether coccoid forms of *H. pylori* can infect humans. Molecular-typing techniques such as ribotyping or restriction fragment length polymorphism are expected to help trace the route of transmission in future epidemiological studies of transmission that should be longitudinal and adequately controlled for the likely confounders of the association between risk factors and *H. pylori* infection.

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