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Review

Helicobacter pylori infection and transmission in Africa: Household hygiene and water sources are plausible factors exacerbating spread

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***Helicobacter pylori* (*H. pylori*) is a microaerophilic motile curve rod that inhabits the gastric mucosa of the human stomach. The organism chronically infects billions of people worldwide and is one of the most genetically diverse of bacterial species. Infection with the bacterium which leads to chronic gastritis, peptic ulceration, gastric cancers and gastric malt lymphoma has been reported to follow a pattern linked to geographic and socio-demographic factors. Studies have documented a higher prevalence in Africa than elsewhere although the pathological outcomes do not correlate with infection. *H. pylori* transmission pathways are still vague, but the risks of transmission include precarious hygiene standards, over-crowding and contaminated environment and water sources amongst others. The possible routes of transmission include oral-oral, faecal-oral and person- to -person, either with or without transitional transmission steps during episodes of diarrhoea or gastro-oral contact in the event of vomiting. Use of contaminated water including municipal tap water has also been suspected to have a high impact in the transmission of the organism. To generate the data presented in this paper, we conducted an internet based search on relevant literature pertaining to *H. pylori* epidemiology in general and Africa in particular. Sites such as Pubmed, AJOL, Scopus and Goggle scholar were mainly used. This paper therefore attempts to appraise the role of household hygiene and water sources in the transmission of this organism in the developing world context.**

Key words: *H. pylori*, Africa, prevalence, transmission, socio-economic factors, environmental factors, hygiene.

INTRODUCTION

Ranked as a class one carcinogen (Peterson et al., 2000; Aguemon et al., 2005), *Helicobacter pylori* is a micro-aerophilic gram-negative coccobacillus (0.5 µm wide by 2 - 4 µm long), equipped with two to six flagella that has chronically infected more than half of the world's population (Owen, 1998; Ding et al., 2001; Ndip et al., 2004; Ahmed et al., 2007; Tanih et al., 2008). Although most of the people harboring this organism are asymptomatic, substantial evidence has linked the bacterium in the pathogenesis and development of certain diseases such as gastric ulcers, chronic gastritis and stomach cancers (MacKay et al., 2003; Iso et al., 2005; Braganca et al., 2007; Tanih et al., 2009).

Whilst a lot of studies have tried to address the transmission modes of *H. pylori*, its transmission pathways are still vague (Dowsett et al., 1999; MacKay et al., 2003; Fujimura et al., 2004; Delport and Merwe, 2007). Elucidation of the paramount role played by household hygiene backed by domestic water quality in the transmission of bacterial pathogens is of great importance as a prophylactic move, both in developed and in developing countries (Brown, 2000). Several studies have highlighted the transmission incidence to range from simple to inevitable multifactor modes (Fujimura et al., 2004; Konno et al., 2005; Perry et al., 2006; Delport et al., 2006; Delport and Merwe, 2007). Highly ostensible promoting features

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which are mostly associated with developing countries and lower socio-economic groups in the developed world include precarious hygiene standards, crowded households, deficient sanitation and contaminated environment and water sources (Ndip et al., 2004; Ahmed et al., 2007). This review is aimed at critically appraising the role of household hygiene and water quality as some of the inevitable profound factors surrounding persistent and high prevalence of this organism in Africa.

H. PYLORI PREVALENCE IN AFRICA

Genetic diversity in *H. pylori* has been shown to decrease with geographic distance from East Africa; simulations have deduced that the organism should have spread from East Africa around 58,000 years ago (Linz et al., 2007). Several studies have highlighted high prevalences of this organism in Africa (Holcombe et al., 1994; Bakka and Salih, 2002; Delport et al., 2006; Fritz et al., 2006; Frenck et al., 2006; Mbulaiteye et al., 2006; Levin et al., 2007; Ndip et al., 2008a). There is an estimate of more than 80% of Africans infected with *H. pylori*, but their rate of developing gastric cancer is lower (McFarlane et al., 2000; Campbell et al., 2001; Louw et al., 2001). Dating back as the early 90s, a high prevalence (80%) of the organism and gastritis in an asymptomatic population was documented (Holcombe et al., 1994).

The onset of infection is from childhood, which once established may persist throughout life (Pelsar et al., 1997; Ndip et al., 2004; Aguemon et al., 2005; Konno et al., 2005; Frenck et al., 2006; Tanih et al., 2009). However, from a study in Tanzania, seropositivity rose steeply with age from 76% in children aged 0 - 4 years to 99% in adults (Mbulaiteye et al., 2006). In another study in Egypt, a high prevalence (72.38%) of infection was noted among school children (Mohammad et al., 2008). In Bloemfontein, South Africa, a study detected a high prevalence (67 - 84%) of *H. pylori* antibodies in children (Pelsar et al., 1997); in yet another study, *H. pylori* IgG antibodies were also detected from South African children and their mothers (Mosane et al., 2004). In Ivory Coast, 55% of children aged less than 10 years have been reported to be infected. In Nigerian children, the sero-positivity rate rose from 57 to 82% in children between 5 - 9 years of age (Holcombe et al., 1992).

Recently, in a South African population studied by Fritz et al. (2006), *H. pylori* prevalence was observed to be 83.3% which is not significantly different to the 84% noted in another study conducted in Pretoria from asymptomatic individuals. Also, a similar trend was noted in Lybia where prevalence rose with age (> 70 years) up to about 94% (Bakka and Salih, 2002). In Cameroon, high incidences of 52.27% and recently of 92.2% *H. pylori* infections were reported in both asymptomatic and symptomatic individuals respectively (Ndip et al., 2004, 2008a). In Tunisia, high colonization rates have also been recorded among asymptomatic individuals (Ammar et al., 2003). In a separate study, low socio-economic level constituted a main risk factor in asymptomatic Tunisian children (Maherzi et al., 2003). In Egypt, *H. pylori* prevalence was reported to be 60% among patients greater than 6 years of age (Frenck et al., 2006), while in a molecular based study in Ethiopia, *H. pylori* strains were detected (71%) in patients with active gastritis (Asrat et al., 2004). An extremely high prevalence (93%) has also been detected among patients with peptic ulcer in Ethiopia (Henriksen et al., 1999).

Bacterial pathogens are emerging with new forms of virulence and new patterns of resistance to antimicrobial agents of which *H. pylori* is not an exception. In an Ethiopian population, molecular analysis demonstrated that more than 80% of Ethiopian *H. pylori* strains harbour both *vacA* and *cagA* genes (Asrat et al., 2004). In a Sowetan study (South Africa) of asymptomatic children aged 6-15 years, 86.5% were infected with *vacA* positive and 87% with *cagA*-positive strains respectively. The majority of the *vacA* strains carried *vacA* s1 allele whilst most of the *cag*-negatives carried the *vacA* s2 allele (Ally et al., 1999). In a separate study, *vacA* diversity was demonstrated among South African *H. pylori* strains, interestingly, no strains with the *vacA* s1a genotype were found among *H. pylori* isolates from black or mixed-race South Africans (Letley et al., 1999). In a study done in Ethiopia, most of the strains were highly resistant to metronidazole; while others were intermediately resistant against doxycycline (Henriksen et al., 1999). In a separate study, 76 and 6% of strains were resistant to metronidazole and amoxicillin respectively (Asrat et al., 2004). This could be of clinical importance with regard to treatment failure in such a highly infected population.

RISK FACTORS AND TRANSMISSION OF *H. PYLORI*

H. pylori prevalence and the rate of infection are inversely related to the standard of living and sanitary practice as revealed by a very high prevalence, especially in developing countries and in lower socio-economic groups in the developed world (Bardhan, 1997; Malaty et al., 1998; Ahmed et al., 2007; Dube et al., 2009). Water purification, improved hygiene, reduced environmental contamination, immunization (vaccination) and antibiotic treatment have played an important role in reducing the morbidity and mortality of bacterial disease especially in the developed world where these are acceptable cultural practices (Perry et al., 2006).

Although an important pathogen of medical significance, *H. pylori* transmission pathways are still vague (Mosane et al., 2004; Braganca et al., 2007) and currently more than 50% of the world's population is infected. The risks of transmission include precarious hygiene standards, crowding and contaminated environment and water sources (Bunn et al., 2002, Suerbaum and Michetti,

2002; Adams et al., 2003; Dube et al., 2009). The possible routes of transmission include oral-oral and faecal-oral, either with or without transitional transmission steps (Vaira et al., 2001; Ahmed et al., 2006) during episodes of diarrhoea or gastro-oral contact in the event of vomiting (Delport and Merwe, 2007). Person- to - person transmission can be a possible cause of infection (Brown et al., 2002). Use of contaminated water including municipal tap water has also been suspected to have a high impact in the transmission of *H. pylori* (Ahmed et al., 2006). Recently, there has been an alarming report of 74.8% infection among people who drank tap water (Ahmed et al., 2007). It has also been suggested that faecally contaminated water has the potential for transmission by the faecal-oral route since the organism can survive several days in water (Lu et al., 2002). In addition, a positive correlation was observed in children who swum in swimming pools, rivers and streams (Goodman et al., 1996).

Africa, which is still burdened with a developmental vacuum, has succumbed deeply to such pathogenic bacteria with incidence of infection reaching up to 99% in adults (Mbulaiteye et al., 2006). Poor economies make it difficult for governments to improve sanitation, access to safe water and food hygiene (Aoki et al., 2004). Civil unrest is also likely to fuel infection rates since a significant number of people tend to be exposed to unhygienic standards. Also, poor planning or poor risk assessment with reference to relocation of people tend to expose people to such precarious hygiene standards hence increasing chances of infections by bacterial pathogens. In some countries political unrest and economic quagmire have led to migration of people resulting in resettlement elsewhere hampered with poor hygiene standards. This also has resulted in increased number of people living/ sleeping in the same house. Such significant crowded living conditions may heighten the potential for a person-to-person transmission pathway of the organism (Malaty et al., 1998; Vaira et al., 2001).

Identification of the source and route of transmission is important as a prophylactic strategy. While a study in Guatemala led to a conclusion that *H. pylori* is unlikely to be transmitted by water (Steinberg et al., 2004), some epidemiological studies have shown that its rate of infection is dependent on water sources (Lu et al., 2002; Braganca et al., 2007).

Because of the ubiquitous nature and high morbidity of *H. pylori* infection, the United States Environmental Protection Agency Office of Ground and Drinking Water expressed concern over possible waterborne transmission by the organism; thereby adding *H. pylori* to its list of potential pathogen that could contaminate water sources (Federal register, 1997; Dube et al. 2009). In developing countries, Water remains the major source of transmission of enteric pathogens. In a study to assess the impact of town planning, infrastructure, sanitation and rainfall on the bacteriological quality of domestic water supplies in Lagos, Nigeria, faults in pipelines, ostensibly resulting from illegal practices of tapping into the distribution system and pipes aging, along with their location near or across a drainage system were strongly correlated with a high level of contamination of pipe-borne water supplies ($p < 0.05$) (Egwari and Aboaba, 2002; Dube et al. 2009). Presumptive evidence of waterborne transmission was first provided by Klein et al. (1991) who found that Peruvian children whose homes had an external water supply were three times more likely to be infected with *H. pylori* than children whose homes had an internal water source.

In a recent study however, all morphological forms of the organism (spiral, rod and coccoid) were observed in drinking water as well as in biofilms (Braganca et al., 2007). This situation may be a potential transmission route in Africa where people store water in containers for several days, under conditions which may favour the development of biofilms. It has been demonstrated that this organism, like others that form biofilms could resist disinfection practices normally used in drinking water treatment in the viable but non-culturable form (Moreno et al., 2007). Survival of this pathogen in chlorinated water has been suggested to be linked to its superior resistance when compared to *Escherichia coli* in reference to chlorinated water. Also, organisms such as *Acanthamoeba castellanii* have been shown to promote the survival of the pathogen under experimental conditions (Winiecka-Krusnell et al., 2002). It has also been observed that *H. pylori* cells can remain culturable longer in cooler waters (< 20°C) than in warmer waters (> 20°C) (Gribbon and Barer, 1995). Substantial evidence exist to suggest that *H. pylori* can live for several days in milk and tap water in its infectious bacillary form and in river water for several months in a coccoid form (Brown., 2000) which is non-culturable but viable (She et al., 2003; Azevedo et al., 2007). This could therefore constitute a potential route of transmission in Africa where some pastoralists' consume unpasteurized milk.

In a study in Japan, the presence of *H. pylori* in drinking and sewage water samples by conventional and PCR assays provided further evidence that waterborne transmission may be important, especially in areas of the world that have high rates of *H. pylori* infection and less than adequate water quality (Horiuch et al., 2000; Karita et al., 2003). Based on the PCR assay, the roles of household hygiene and water source in the prevalence and transmission of *H. pylori* infection in a selected population of 500 adults with upper gastrointestinal tract symptoms was also investigated in a South Indian population by Ahmed et al. (2007). They reported an overall *H. pylori* prevalence of 80%. They also noted that the prevalence of infection among people who drank water from wells was 92% compared with 74.8% of those who drank tap water ($p < 0.001$). A similar study by Benson et al. (2004) detected *H. pylori* in water by PCR.

H. pylori has been isolated or detected in the faeces of

adults and children using culture techniques, the HpSA test and PCR (Thomas et al., 1992; Mapstone et al., 1993; Shepherd et al., 2000; Ndip et al., 2004; Ceylan et al., 2007). With the view that a positive correlation of infection and faecal pollution has been demonstrated (Queralt et al., 2004), limited sanitation services in Africa can unavoidably lead to faecal contamination of the environment as well as water sources. Hence, playing habits such as swimming in river or dam water has the capacity to accelerate the rate of infection, especially in a rural African population.

Several studies have documented that most people acquire *H. pylori* infection during childhood (Malaty et al., 1998; Goodman and Correa, 1995; Rowland, 2000). DNA fingerprinting studies have confirmed the similarity of strains from children and those from their mothers there by suggesting a possibility of mother-to-child transmission (Delport et al., 2006). Intraspecific transmission from mother to child has been linked to premastication of food (Mégraud, 1995). In addition, use of common spoons, licking pacifiers or teats of feeding bottles by other subjects may result in transmission (Rothenbacher et al., 1999). Also, a strong evidence for a transmission pathway from family members to children was recently observed (Ceylan et al., 2007).

The role of the oral cavity as a transmission pathway had been proposed. However, controversy still exists regarding this route (Olivier et al., 2006). In a recent study in South Africa, it was reported that the oral cavity is unlikely to contribute to the spread of this organism as oral cavities were found not to favour prolonged colonization by the organism (Olivier et al., 2006). In the same study, *H. pylori* was not detected from dental plaque samples by PCR even though 84% of the healthy subjects had tested positive to the antigen.

Besides the oral-oral route, transmission of *H. pylori* also takes place through the consumption of contaminated food. However, faecal-oral transmission may be more important than oral- oral contact in the spread of the organism, although both routes may co-exist (Bardhan, 1997). Also a zoonotic reservoir of the organism and a possible transmission from animals to humans has been reported (Papiez et al., 2003; Dore et al., 2001). Iatrogenic transmission can take place during anatomical pathology when contaminated colonoscopies, endoscopes or biopsies are introduced to a patient (Mendall et al., 1992; Akamatsu et al., 1996).

HOUSEHOLD HYGIENE

Several studies have been conducted to relate *H. pylori* prevalence with household hygiene. Its prevalence has been observed to be higher within families that use non-flush toilets, outdoor toilets, outdoor water taps and use of river water (Ndip et al., 2004; Dube et al., 2009). Most of the findings show that poor hygiene has a positive correlation with increased prevalence of the organism. Safe disposal of human excreta is the first step in preventing faeco-oral and other routes of disease transmission as improved sanitation standards reduce contamination of the environment (Dube et al., 2009).

Poor sanitation, such as the lack of sanitary services at home, is believed to be an important risk factor for *H. pylori* infection (Mendall et al., 1992). Impaired hygiene during childhood especially in developing countries seems to be associated with a higher prevalence of the organism. Sharing cups, premastication of food for young children, sharing water for bathing and washing hands and limited sanitary facilities have been shown to be having a positive correlation with increased prevalence of the organism (Ndip et al., 2004).

Keeping animals is a necessary but inevitable evil in *H. pylori* transmission. Previous serological studies have shown a higher prevalence of antibodies against *H. pylori* in some professions (abattoir workers, shepherds, veterinaries) probably due to direct contact with *H. pylori* infected animals (Vaira et al., 2001; Dore et al., 2001; Papiez et al., 2003). Most Africans practice subsistence farming with almost all homesteads keeping domestic animals; several studies have shown a possibility of transmission pathway through domestic cats, dogs and sheep (Dore et al., 2001; Papiez et al., 2003).

A possible means of transmission has also been related to the milking procedure, which has not improved for centuries in the developing world (Papiez et al., 2003). While milk-boiling practices might be practiced worldwide as a means of sterilization, breast to mouth milking are common in Africa. This probably could be another avenue for *H. pylori* transmission. *H. pylori* prevalence is therefore inevitably linked to poor social and hygienic status and zoonotic reservoirs (Imrie et al., 2001).

WATER SOURCES

Clean water is essential to life. In Africa, there is still a lot to be done to achieve the standard of Clean Water Index (CWI) recommended by the word Health Organisation (WHO). A study in Kazakhstan, defined clean water index based on the consistency of boiling water before drinking, the frequency of storing and reusing water and the frequency of bathing and showering. In this study, *H. pylori* infection was inversely correlated with CWI [56, 79 and 95% for high, middle and low, respectively ($p < 0.05$)]. Further the authors documented the finding that, drinking river water had highest risk of *H. pylori* infection (OR = 13.6, 95% CI = 1.8 - 102.4; $p < 0.01$, compared with tap water) (Brown et al., 2002).

Water is still a challenge towards the control of microbial infections, hence, focus on how best to improve water quality within the 200 m radius, a standard required by the WHO, will be a step towards control of water transmission of micro-organisms including *H. pylori*. Intervention techniques employed to treat water include physical removal of pathogens (e.g. filtration, sedimentation and

adsorption), chemical treatment (e.g. assisted sedimentation, chemical disinfection and ion exchange) and heat and ultra violet (UV) radiation. In Africa, domestic water sources range from indoor tap water to the most ancient forms such as direct dam or river water from which the presence of the antigen cannot be ruled out (Braganca et al., 2007). Bacteriological water quality mainly rely on type of disinfectants used and ability to sustain enough residual concentrations, the concentration of biodegradable compounds in water as well as prevailing water temperature and the piping material used (Riley et al., 2002; Azevedo et al., 2007).

Protected wells, groundwater and rain water are other forms of domestic water commonly used in Africa. Whilst containers can be provided to store clean water for drinking and domestic use, there are risks of contamination linked with the method such as during transporttation, storage and during domestic use (MacKay et al., 2003; Momba et al., 2005). Several studies have highlighted the presence of the organism or its DNA in water (Bunn et al., 2002; She et al., 2003; Azevedo et al., 2007).

In a Council for Scientific and Industrial Research (CSIR) report, it was estimated that only 21% of South African households have access to piped water within their homes**.** Also 43.3 and 30% of the population in Mangwe and Beitbridge in Zimbabwe were found to be using unprotected water (Nala et al., 2003). In Tanzania, 67% of both rural and urban populations were reported to be having access to clean and safe water (Aoki et al., 2004).

Furthermore, shortage of funds in African countries impact on the operation of sewage systems that is below standard with rural populations using latrines thereby unavoidably increasing chances of faecal contamination of water sources (Aoki et al., 2004). Since faecal contaminated water has the potential for faecal-oral transmission of the organism (Lu et al., 2002), most Africans might be at risk of becoming infected with the organism due to the primitive water sources that are still the main water sources in some communities.

An earlier study demonstrated that water-borne transmission of *H. pylori* could be an important source of infection in developing countries, especially if the water supply is vulnerable to bacterial contamination and is untreated (Papiez et al., 2003; Nala et al., 2003) *H. pylori* has the ability to remain culturable in natural waters at a low temperature (Gribbon and Barer, 1995). Since under unfavourable conditions *H. pylori* turns to a nonculturable form (Sörberg et al., 1996), there is still a need to demonstrate the conversion to a bacillary form so as to prove the involvement of the coccoid form in the transmission and waning nature of the infection. However, an earlier study had demonstrated that the coccoid forms do not lose completely the maintenance factors or properties and might be able to infect mice (Cellini et al., 1994; She et al., 2003) thereby strengthening the argument of the possibility of transmission by the coccoid form. Use of boiled or filtered water would be an exploitative idea as it has been shown to reduce infection (Ahmed et al., 2006).

In Africa, especially in rural areas, there are lots of deep-rooted behaviours that could unavoidable result in infection. Children tend to bath and swim in river water which is highly likely to be contaminated by both animal and human faeces. Also vegetables are watered by untreated water including direct dam water thereby giving room for transmission through eating contaminated vegetables, especially those eaten raw as studies have suggested that the organism could be transmitted through the consumption of contaminated vegetables (Hopkins et al., 1993).

Conclusion

Albeit the enormity of studies conducted worldwide on the transmission of *H. pylori*, the transmission route of this pathogen remains elusive. Poor socio-economic factors encompassing over crowding, poor sanitation practices and contaminated environment and water sources which are highly associated with poor household hygiene, features common in Africa seem to play an important role in the transmission of this organism.

Although *H. pylori* infections are treatable using the triple combination regimen, resistance to these drugs posses a serious challenge especially in Africa (Ndip et al., 2008; Tanih et al., 2009) where there is rampant misuse of antibiotics coupled with the lack of funds to access treatment. However, hope lies in the use of natural compounds with anti-*H. pylori* activity from medicinal plants and honey which are cheap and readily available to the communities (Ndip et al., 2007a, b, 2008b) as a means to curb the infection.

Education of the masses highlighting the relevance of good hygiene and sanitation in the form of seminars, pamphlets, posters, radio and television messages or cluster group discussions need to be encouraged in African communities to help curb infection rates, since several studies have highlighted increased prevalence of the pathogen with low level of education. Also, governments should take the political will of providing potable water to all communities.

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