HL cavanoian Aboriginals and recent immigrants are among populations in which the prevalence of Helicobacter pylori infection remains high; hence, the health risks imposed by H pylori remain a significant concern. Therefore, The Canadian Helicobacter Study Group held a conference that brought together experts in the field to address these issues, the results of which are reviewed in the present article. Canadians with the highest prevalence of H pylori infection are an appropriate focus for considering the health advantages of eradicating persistent infection. In Canadian communities with a high prevalence of both H pylori and gastric cancer, there remains an opportunity to test the hypothesis that H pylori infection is a treatable risk factor for malignancy.

Key Words: Gastric cancer; Helicobacter pylori; Immigrants; Native Canadians

H pylori is a Gram-negative bacterium that typically colonizes the mucin layer of the gastric mucosal epithelium (1). At one time, it is likely that H pylori infected the majority of the human population (2). Infection is strongly correlated with human crowding and poor sanitation (3). The prevalence of infection has diminished markedly over the past several decades in Canada, as in most other industrialized countries, but can be found in up to 80% of the population in some developing nations (4). The overall prevalence of H pylori infection in Canada appears to be in the range of 20% to 30% (5,6); however, reports from specific subsets of the population indicate substantial variability. In children, who typically have a lower risk of infection than adults, the prevalence rate was only 7.1% in patients referred to a tertiary care centre for upper gastrointestinal symptoms (7). The median age in these patients was 11.7 years, with a range of five to 17.6 years. Conversely, the prevalence in a First Nations community in northern Manitoba was 58%, even though ages

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The inflammatory response within the gastric mucosa that is observed in individuals infected with *H pylori* infection likely contributes to the risk of neoplasia. Inflammation from stimuli such as infection or irritation is a well demonstrated cause of cancer in other anatomical sites including the colon, cervix and lungs (29). In the gastric mucosa, as in other sites, the dysregulation of cell cycles and increased cell turnover that is driven by cytokines and growth factors is believed to increase the risk of neoplastic mutations (30). In a study of gastric biopsies taken from 70 patients of which approximately one-half were infected with *H pylori* (31), stratification according to those with normal epithelia, gastritis, gastritis with intestinal metaplasia or gastric carcinoma revealed increased epithelial cell turnover in the presence of gastritis even in the absence of metaplasia. Moreover, eradication of *H pylori* was associated with a reduction in gastritis and cell proliferation, which in turn would be expected to reduce the risk of dysplasia and its potential to promote mutation.

The RR for gastric carcinoma may be mediated by a wide variety of factors characteristic of the specific strain or of the host. Virulence factors, such as CagA or Vac status, which appear to be useful for identifying *H pylori*-infected patients with a high risk of progressing to neoplastic lesions (32), may not have any direct carcinogenic effects, but increase risk of dysplastic mutations and cancer by increasing the degree of inflammation (33). Specific histological or clinical characteristics associated with increased gastric cancer risk, such as atrophy, intestinal metaplasia and achlorhydria, may also be linked to these or other virulence factors (34). However, the host response both with regard to inflammation and to the downstream molecular events that may mediate specific steps toward malignant transformation may be heterogeneous. For example, one of many proposed pathways of malignancy is upregulation of interleukin-6, which is linked to activation of the transcription factor STAT3. STAT3, a promoter of epithelial cell hyperproliferation in animal models, has been found to be upregulated in biopsies taken from human gastric cancers (35). In this and other examples, multiple feedback mechanisms, as well as redundant and interrelated molecular signaling that affect cytokine expression and protein phosphorylation, may explain unequal RR for a trajectory from inflammation to malignancy (36). The mechanisms by which *H pylori* promotes gastric cancer, particularly the relative role of virulence factors and their relationship to intestinal metaplasia, are important for understanding the potential benefit of eradication for preventing or halting the neoplastic process. However, the timing of eradication is likely to be critical because the pathophysiology may no longer be dependent on the presence of *H pylori* infection once the process has been initiated. In a prospective study that randomly assigned patients with or without precancerous lesions to *H pylori* eradication, no cancers developed during a 7.5 year follow-up period after eradication in those without precancerous lesions, whereas eradication had no protective effect in patients with precancerous lesions when compared with placebo (28). The potential importance of eradicating *H pylori* before the development of intestinal metaplasia is an important consideration when attempting to calculate the health benefit from a population-based eradication program. Due to the prolonged latency period between infection and cancer, clinical studies capable of demonstrating benefit will require follow-up for a decade or longer in a patient population with both a high prevalence of *H pylori* infection and a high incidence of gastric cancer. Despite the falling rates of *H pylori* infection in Canada, studies of the feasibility of a population-based eradication program in high-risk populations have been recommended previously (37). Aboriginals, particularly those in Arctic communities, and selected immigrant groups appear to be attractive targets of such initiatives.

**POPULATIONS AT RISK IN CANADA**

**Native Canadians**

The most significant effort to evaluate the health risks posed by *H pylori* infection in Canadian populations with a high prevalence of infection was initiated in 2006 by the Canadian North Helicobacter pylori...
Working Group (CANHelp), which was specifically created to evaluate
the impact of *H pylori* infection among individuals living in
Canada’s Arctic communities (38,39). The initial impetus for this
effort was the concern among health providers regarding the high
rate of gastric cancer in Aklavik, Northwest Territories, relative to
non-Aboriginals in Canada (39). In an initial survey conducted in
2008 involving the urea breath test (UBT), the rate of *H pylori*
infection in this community was 55% (38), reinforcing concern among
the community members that *H pylori* might be related to the observed
increase in gastric cancer risk. However, prevalence alone may not
account for the risk of gastric cancer. In a study of an Aboriginal
community in northwestern Manitoba, the high seropositive rate of
*H pylori* infection (95%), of which most were positive for the CagA virulence
factor, was consistent with a high rate of hospitalizations for peptic
ulcer disease (9). Two studies that evaluated the prevalence of *H pylori*
among Aboriginals living in Arctic communities of Canada (8,40)
documented a high prevalence of infection in children as well as in
adults. In one, 67% of children were infected by two years of age.
While gastric cancer rates have not always differed in Aboriginals
when compared with non-Aboriginal groups, confounding variables,
such as differences in lifespan, may obscure a relative difference.

Similar concern about an increased prevalence of *H pylori* infec-
tion and gastric cancer has been raised in other Aboriginal commu-
nities as well as in Arctic communities outside of Canada. In studies
from Greenland, Alaska and Russia, the prevalence of infection ranged
from 47% to 88% (41-43). In a comparison of *H pylori*-related
diseases among Aboriginal populations in the US, those from the
Arctic communities had the highest rates of hospitalization from
peptic ulcer disease, gastric carcinoma and MALT lymphoma (44).
Similar data are needed for Aboriginal communities in Canada.

Based on these observations, several initiatives, in addition to
CANHelp, have been created to investigate the relationship between
*H pylori* infection and risk of upper gastrointestinal diseases, including
gastric cancer. In particular, the Circumpolar Helicobacter Pylori
Working Group (CHPWHG), which includes Canadian participation,
has provided a platform on which to share information. In Alaska,
surveillance data collected by the US Centers for Disease Control
show that the increased prevalence of *H pylori* infection is unique to
individuals living in Aboriginal communities and is not shared by
Alaskans who do not reside in these communities (45). The high rate
of *H pylori* infection was initially identified in a study investigating
the high prevalence of anemia in Aboriginals (46). A variety of etiologi-
factors were evaluated including iron intake, stool parasites and upper
gastrointestinal bleeding, but the anemia was ultimately linked to
gastrointestinal bleeding from *H pylori*-induced gastritis (46,47). In
the US, cancer rates have been traditionally higher in American
Indians versus whites (48,49). In a study that compared Indian popula-
tions from different regions, the incidence rates of cancer were often
more than twice as high for Indians versus non-Hispanic whites
(NHWs) (49). The exception was on the east coast, where Aboriginal
and NHW cancer incidence rates were similar. The differences were
greatest among Alaskan Indians versus NHWs. In patients older than
65 years of age, the rate was more than four times higher among
Alaskan Aboriginals than NHWs (134.5 versus 31.1 per 100,000 [RR
4.33]), and approximately twice as high as the next highest Aboriginal
rate, which was 69.6 per 100,000 among Indians from the Northern
Plains.

The increased prevalence of *H pylori* infection among Aboriginals
is attributed to the same set of factors that account for the high preva-
lence of *H pylori* infection in developing nations (50). These include
many of the consequences of limited economic development, including
crowding, poor living conditions, bed-sharing in childhood, lack of refrigeration,
and lack of running water and other obstacles to regular personal hygiene.
Such conditions are common in many Arctic communities. Independent of
the costs or other obstacles to improving living conditions among
Aboriginals, resistance to change in traditional lifestyles is a potential
obstacle to control of *H pylori* transmission.

**IMMIGRANT POPULATIONS IN CANADA**

Immigrants to Canada from countries with high endemic rates of *H pylori*
infection, such as China or India, continue to demonstrate high
rates of infection relative to the first-generation of the same ethnic
groups born in Canada (5). Because spontaneous eradication of *H pylori*
is uncommon (51), foreign-born Canadians who arrive with this infec-
tion can be expected to harbour this bacterium indefinitely. In a study
of the prevalence and risk factors for *H pylori* infection in Ontario, the
RR for infection was 2.9 times greater among those born in a country
other than Canada and who immigrated after 20 years of age (5). A
similar RR was found for immigrants to the US (52). In a US study
comparing generational differences in the prevalence of infection
among immigrant families from Latin America (53), the age-adjusted
OR for *H pylori* infection was 9.70 for foreign-born adults relative to
the second-generation, although differences fell after additional
adjustments for educational level and crowding.

*H pylori*-infection prevalence in recent immigrants may rival those
observed in some northern Aboriginal communities, but population-
based strategies for eradicating infection and preventing new infection
in immigrants may pose a different set of problems than those faced in
Aboriginal groups. Foreign-born immigrants do not necessarily live in
well-defined communities and, therefore, may be more difficult to iden-
tify for screening and treatment unless screening and treatment is
performed at the time of immigration. Moreover, given the older average
age of immigrants versus Aboriginals, the anticipated reduction in the
rate of infection transmitted to others is lower, so that the benefit from
a test-and-treat strategy may be less. In contrast, greater access to health
care services may lower the cost of a test-and-treat strategy in an urban
immigrant population relative to Aboriginals. The result is that different
calculations may be needed to predict the benefit-to-risk ratio from a
test-and-treat strategy among these two groups, even when prevalence
rates are similar, particularly when calculated in the context of cost.

**CHALLENGES TO ELIMINATING *H PYLORI*
INFECTION IN HIGH-RISK POPULATIONS**

Of the health benefits anticipated from *H pylori* eradication, prevention
of gastric cancer is the most significant perhaps in relation to years of life
saved. According to data from the US (54), only 23% of gastric cancers are
localized at the time of diagnosis. Similar to many other malignan-
cies, the frequency with which gastric cancer is discovered at an
advanced stage, when the opportunity for curative treatment is
diminished, makes prevention an attractive strategy. While populations
with both a high prevalence of *H pylori* infection and a high rate of
gastric cancer constitute a particularly attractive target for public health
initiatives to prevent gastric cancer with *H pylori* eradication, other sig-
nificant health benefits may also be achieved. In particular, prevention
of complicated peptic ulcer disease can be expected to reduce the risk
from life-threatening upper gastrointestinal bleeding.

There are several limitations to consider before initiating a
population-based eradication initiative in any population. In addition
to potential practical barriers, such as gaining consent and support
among a target group, the understanding of biological events that link
infection with the risk of malignancy remains limited. In a prospective
Japanese study that followed 1526 patients with upper gastrointestinal
complaints, including peptic ulcer disease and dyspepsia (14), gastric
cancers occurred exclusively in those with *H pylori* infection, reaching
an incidence of 4.7% in patients with nonulcer dyspepsia over a mean
follow-up period of 7.8 years. However, this study only compared
uninfected individuals rather than those who achieved successful
eradication before infection. There is no evidence that eradication can
eliminate an established malignancy. In a placebo-controlled study
that evaluated the risk of cancer development after eradication,
protection was only observed in patients without precancerous lesions,
deemed as gastric atrophy, intestinal metaplasia or gastric dysplasia,
the time of study entry (28). Based on a study from Japan (55), recur-
cent gastric cancer can be reduced by two-thirds with the eradication
of *H pylori* infection. Although another study by the same group found

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that \(H\) pylori eradication did not prevent cancer in individuals who had already developed atrophic gastritis (56), a population-based strategy of test-and-treat was predicted to reduce gastric cancer rates by more than 80%, yielding large economic benefits.

In Canada, approximately one million individuals identify themselves as Aboriginal, of which approximately 5% are Inuit (57). Given the epidemiology of \(H\) pylori in the human host, an increased prevalence of infection is likely to be limited to Aboriginal communities that harbour risk factors for \(H\) pylori infection, including poor socioeconomic circumstances, crowded living conditions and limited access to running water. The CANHelp initiatives, now supported by data demonstrating a high prevalence of \(H\) pylori infection in isolated Arctic communities, where these conditions are most common, include efforts to reduce health risks by providing information on the sources and strategies to diminish risk exposure. Such initiatives require sensitivity to Aboriginal culture as well as collaboration with community leaders seeking to ensure a community benefit. If adequate data can be collected to anticipate a significant improvement in health from a population-based \(H\) pylori eradication program, buy-in from community leaders and the rest of the community will be essential for successful implementation.

If the benefits of a population-based program for eradication of \(H\) pylori infection are projected to justify the cost, other potential challenges require consideration. The rates of resistance to the antibiotics typically used in the multidrug combinations for eradication appear to be high in Aboriginal communities (K. Goodman, Aklavik \(H\) pylori Project personal communication). To reduce the impact of resistance to commonly used three-drug regimens, several strategies, such as four-drug regimens (58), longer courses of three- or four-drug regimens (59), or the addition of newer, more expensive antibiotics (60), can be effective; however, each of these strategies must be weighed carefully in the context of goals and costs. Moreover, strategies will need to be implemented to enhance adherence. The large volume of literature comparing first-, second- and third-line regimens in areas with high rates of resistance may or may not be useful for guiding treatment choice in a population-based program that may require relatively simple regimens to achieve adequate adherence.

In particular, the traditional first-line eradication regimen endorsed by the Canadian Helicobacter Study Group were twice-daily triple therapies consisting of a proton pump inhibitor and two antibiotics administered for seven days (61). Longer durations of treatment, such as 10 days, or four-drug versus three-drug therapies, can offer modest but potentially clinically significant improvements in eradication rates, particularly among those with resistance to one of the antibiotics in the combination (62,63). Resistance to antibiotics make alternative, often more expensive agents, such as levofloxacin, attractive for boosting eradication rates (64), particularly in patients who have failed a previous regimen (65); however, the ideal characteristics of a regimen for a population-based eradication strategy may be different from those for an individual. Issues such as convenience, cost and adverse events may play a critical role in achieving a level of compliance important to eradication independent of the efficacy of the regimen. For individuals or population-based strategies, second- and, potentially third-line, options must be developed based on the causes of failure, particularly antibiotic resistance (66). This is an area in which evidence regarding the populations of concern discussed in the present article is lacking and, thus, open to investigation.

The foremost goal of any program developed to screen and treat \(H\) pylori infection is a direct benefit for the participants. While comprehensive eradication programs may provide an important opportunity to demonstrate that gastric cancer is a preventable disease, outcomes must be predefined and measured rigorously. While it may not be feasible to document \(H\) pylori eradication in all participants in a community-based screen-and-treat program, it will be prudent to prospectively define adherence, treatment failure, and treatment success for both first- and second-line regimens to document the impact of intervention with regard to benefit, risk and cost. Unlike test-and-treat strategies that reserve therapy for symptomatic patients, a benefit will be measured primarily by a reduced population-based rate of the complications of \(H\) pylori infection.

Protecting immigrant populations with a high prevalence of \(H\) pylori infection and high prevalence of gastric cancer is a potentially important public health initiative. The high prevalence of gastric cancer in several Asian countries, including China and Japan (67), has been reflected in the immigrant populations from those countries in Canada (68). Despite the absence of level-1 evidence that eradication of \(H\) pylori will reduce cancer risk, the circumstantial evidence is strong (69,70). Targeted programs for recent immigrants or for specific immigrant communities are feasible, and should be pursued on the basis of evidence supporting a health benefit.

In the effort to target either Aboriginal or immigrant populations to reduce the risk of gastric cancer, collaboration with these communities will be essential. The history of difficult relations between Aboriginal and non-Aboriginal populations, in particular, may increase the need for evidence of a benefit from an intervention recommended from outside the community.

**ECONOMIC BENEFITS: ANTICIPATING OUTCOMES**

The 2008 Asia-Pacific Consensus Guidelines on Gastric Cancer Prevention (71) recommended a strategy of screening and eradicating \(H\) pylori in high-risk populations, based on the anticipated probability of cancer prevention. The emphasis on high risk is based on the fact that \(H\) pylori infection is a necessary but not sufficient factor for the development of gastric cancer. In cost analyses of test-and-treat eradication schemes, important variables include the cost and sensitivity of the diagnostic test, the cost and efficacy of the treatment, and the anticipated reduction in cancer risk. Based on assumptions used in one of the earliest models (72), the projected cost per year of life saved in the US was US$25,000. A commonly accepted benchmark for an acceptable per year of life cost is dialysis, which is typically calculated to cost between US$50,000 and US$100,000 per year of life saved (73). When the assumptions of test sensitivity and treatment efficacy were made less favourable, the costs exceeded those that are usually acceptable for the general population, but remained attractive for Japanese Americans, the highest risk group.

In a recent study conducted in Korea (74), where the prevalence of \(H\) pylori infection and gastric cancer were relatively high, the model for a test-and-treat strategy projected a modest reduction in cost ($US800) relative to no eradication. The savings derived from an anticipated reduction in gastric cancer were accompanied by a small mortality reduction. In a simulation model conducted among ethnic Chinese males living in Singapore, the projected incremental cost effectiveness of test-and-treat was US$16,166 per life year saved when serology was used as the screening tool, but rose to $38,792 per life year saved with the more sensitive and specific UBT (75). Moreover, unlike the UBT, the relative cost efficacy of serology was found to remain substantial even with large changes in the underlying assumptions, such as lowering the rate of expected infection. In a model constructed with data from China, screening and treatment for \(H\) pylori infection at 20 years of age reduced the mean lifetime cancer risk by 14.5% in men and 26.6% in women at an anticipated cost of less than $US1,500 per year of life saved (76).

From a public health perspective, these models anticipate a reasonable return from a test-and-treat strategy in high-risk patients. However, the underlying premise that gastric cancer will be prevented with \(H\) pylori eradication remains circumstantial. Although epidemiological data support the notion that individuals without \(H\) pylori infection have a very low risk of gastric cancer relative to those infected, the process of carcinogenesis is not likely to be reversible once infection has been present for an, as yet, undetermined period of time. Based on the current understanding of the relationship between gastritis, proinflammatory cytokines, hyperproliferation of epithelial cells and malignant transformation, the potential for eradication to reverse the risk of cancer remains a reasonable expectation. However, the timing is likely to be important and it may be essential to eradicate
H pylori before premalignant dysplastic lesions develop in areas of atrophic gastritis. In regions with a high incidence of H pylori infection and gastric cancer, as suggested by the limited data from Arctic Aboriginal communities in Canada (38, K Goodman, Aklavik H pylori Project personal communication), the opportunity to prevent gastric cancer with a test-and-treat approach to H pylori infection is considerable but, in reality, is unlikely to be proven in the short term in a prospective randomized controlled trial. Even if test-and-treat strategies lower gastric cancer risk, the anticipated risks and benefits will vary substantially with the relative efficacy of the eradication regimen.

**SUMMARY**

The high prevalence of H pylori infection and gastric cancer in Canadian Aboriginal communities presents an important opportunity to pursue a clinical research initiative for gastric cancer prevention. Moreover, programs that merge basic and clinical research with the goal of creating realistic and effective public health programs to control H pylori infection in Aboriginals have the potential to yield information on the relationship between this pathogen and gastric cancer in other populations. Funding for new research and existing programs such as CANHelp should be considered an urgent priority because of the potential for a large overall public health benefit in these high-risk groups. The considerable data already generated by studies conducted in Canada and elsewhere support the current need for a focused effort to determine whether H pylori eradication reduces the risk of gastric cancer. As reviewed in the present document, Aboriginal populations may provide the best target for clinical research that will answer this question. Such studies, which have a strong potential to yield health benefits to the study participants, may increase our understanding of the role of H pylori and other environmental and genetic factors in the multifactorial pathogenesis of gastric cancer.

The Arctic Aboriginal communities within Canada offer an exceptional target for public health initiatives regarding H pylori infection. Adverse health consequences, including a high prevalence of gastric cancer associated with H pylori infection, are already known. The substantial potential public health benefit is supported by the suitability of the isolated and insular Aboriginal communities for tracking the impact of a test-and-treat intervention. Within Canadian health care, investment in this research could be cost-effective if confined to the target populations. This investment has the additional potential to yield information relevant for managing gastric cancer risk in non-Aboriginal groups.

There are important hurdles. The Aboriginal communities must agree that cooperation in this research is likely to produce direct benefit. Additional studies are needed to document H pylori infection prevalence and gastric cancer risk in those communities that are potential partners in this research. Detailed projections of sensitivity and cost will be needed to select the most appropriate screening test. Appropriate eradication regimens must be selected on the basis of efficacy and adherence, with particular attention devoted to antibiotic resistance rates in the Arctic Aboriginal populations. The transparency of research methods is essential for informed consent, and well-defined outcome measures are essential to document community benefit.

The Canadian Helicobacter Study Group advocates research that will determine whether a population-based test-and-treat strategy for H pylori is a feasible clinical initiative in the Arctic and immigrant populations. The large potential public health benefit to Canadians, including Aboriginal groups, and the state of current knowledge encourages this direction of research. Funding of this research with public monies has a strong probability of improving the health of Canadians.

**ACKNOWLEDGMENTS:** The authors thank Michael Bruce MD, MPH, Epidemiology Team Leader Arctic Investigations Program, US Centers for Disease Control and Prevention (USA) who presented a comprehensive information-sharing talk and contributed to fruitful discussion at the conference. They also thank medical writer Ted Esworthy for keeping a record of the meeting and constructing the initial draft of the manuscript, and The Canadian Helicobacter Study Group for providing financial support for the conference.

**APPENDIX**

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*H pylori* in First Nations and immigrant populations