Effects of *Helicobacter pylori* Infection on Gut Appetite Peptide (Leptin, Ghrelin) Expression in Elderly Inpatients

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The aim of the study was to investigate the relationship between gastritis and leptin and ghrelin in elderly patients. Patients older than 75 years undergoing an endoscopy were included. We reported data on nutritional status and *Helicobacter pylori* infection diagnosis (serology, 13C-urea breath test, culture, histology, and polymerase chain reaction on gastric biopsies). Gastric messenger RNA expression of leptin and ghrelin were quantified by real-time polymerase chain reaction. Sixty-two patients were included (84.7 ± 5.2 years). *H. pylori* infection was associated with decreased gastric expression of leptin (p = 0.021), ghrelin (p = 0.002), and plasma ghrelin levels (p = 0.018). Atrophy was associated with decreased gastric leptin (p = 0.007) and ghrelin (p = 0.02). *H. pylori* infection correlated negatively with patient energy intake (r = −0.36; p = 0.007) and body mass index (r = −0.34; p = 0.018). The negative association between ghrelin and *H. pylori* infection may be related to a higher prevalence of atrophy and raises the possibility that *H. pylori* may be contributing to undernutrition in some older people.

Aging results in a dysregulation of the ability to regulate food intake. The mechanisms responsible for anorexia are not well understood, but they may predispose older people to the development of protein-energy malnutrition, which is associated with increased morbidity and mortality (1). Many sensory and social factors, including olfactory changes and economic status, contribute to undernutrition in older people; however, anorexia is frequently associated with a number of gastrointestinal pathologies such as peptic ulcer disease or gastritis due to *Helicobacter pylori* infection (2). Studies reported that, in young adults, successful eradication of *H. pylori* infection can lead to improved appetite followed by increased body weight (3). The recent identification of appetite-regulating humoral factors revealed that regulatory mechanisms exist not only in the central nervous system but also in peripheral tissues, that is, gastric tissue (2).

Leptin, a 146-amino-acid peptide, synthesized mainly by the adipose tissue, is involved in the regulation of food intake, body composition, and energy expenditure through a central feedback mechanism (4). It is an anorexigenic hormone that induces satiety by activating hypothalamic neurons, proopiomelanocortin, and cocaine- and amphetamine related transcripts. Recently, Bado and colleagues and Sobhani and colleagues (5,6) reported that the stomach is a source of leptin, and they isolated leptin messenger RNA (mRNA) and the corresponding protein in rat and human fundic gastric epithelium. It has also been reported that gastric leptin induces postprandial satiety by a neuroendocrine mechanism via activation of leptin receptor proteins in afferent and efferent neurons of the vagus nerve (7).

Ghrelin, a 28-amino-acid peptide, is also a recently discovered growth hormone (GH)–releasing peptide that stimulates GH release, increases appetite, and facilitates fat storage. It is an orexigenic hormone that potentially stimulates feeding by activating hypothalamic neurons, which in turn secrete anabolic substances, neuropeptide Y, and agouti-related protein. Ghrelin is produced mainly in the mucosal epithelium of the stomach (corpus), and is secreted in blood vessels, thereby circulating throughout the whole body (8,9).

Therefore, we hypothesize that chronic persistent damage of the gastric mucosa, such as chronic gastritis, might affect leptin and/or ghrelin synthesis, leading to changes in food intake and body weight. The aim of our study was to investigate the relationship between chronic gastritis associated with *H. pylori* infection and: (a) leptin and ghrelin gastric expression, and (b) circulating leptin and ghrelin, and to look for an eventual relationship between nutritional status and these parameters in elderly patients.

**METHODS**

**Clinical Samples**

Patients (a) older than 75 years, (b) hospitalized in the acute care unit of the University Department of Geriatrics.
(Hôpital Xavier Arnozan, Pessac, France), and (c) requiring a gastrointestinal endoscopy were recruited from February 2004 through February 2005. The acute care unit is a general geriatric unit, characterized by a short stay (mean length: 15.3 days), where patients are admitted for any medical reasons. Exclusion criteria were contraindications for endoscopy and/or biopsy sampling or refusal to consent. All patients gave their written informed consent, and the study protocol conformed to the 1975 Declaration of Helsinki and was approved by the Ethics Committee of our institution. A geriatric assessment was carried out for all included patients, that is, Activities of Daily Living (ADL) (10), the 5-item Geriatric Depression Scale (GDS) (11), and the Mini-Mental State Examination (MMSE) (12).

The geriatric assessment also included a nutritional evaluation, that is, body mass index (BMI; kg/m²), energy intake (kcal/day), and plasma albumin level (normal range: 35–45 g/L). We used the previously reported visual method for estimating meal intake during hospitalization, which permitted the exact quantification of energy and protein intake by a dietician or an immediate but visual rough estimation by the nursing staff (13).

Endoscopy and Biopsy Sampling

All endoscopies were performed by the same gastroenterologist in the University Department of Gastroenterology by using an Olympus GIF 100 or 130 video endoscope (Rungis, France). At least two antral and three corpus biopsy specimens were collected from each patient. A total of two antral and two corpus biopsy specimens were used for histological analysis and culture (one antral and one corpus biopsy for each analysis). One corpus biopsy specimen was collected from each patient for mRNA extraction. The biopsies were processed for histological examination using the standard procedures. Hematoxylin and eosin staining as well as a special staining for H. pylori (Giemsa) were performed as previously reported (16). Results were interpreted according to the Sydney classification (17) by an expert pathologist blinded for patient characteristics.

Culture of gastric biopsy specimens.—One antral and one corpus biopsy specimen were introduced into a Portagerm pylori transport medium (bioMérieux, Marcy l’Etoile, France) and sent by courier in a cool transport container (Sarstedt, Orsay, France) for culture to the Centre National de Référence des Campylobacters et Helicobacters (Université Victor Segalen, Bordeaux, France). All of the specimens were plated on the same day as the endoscopy took place. They were processed according to a protocol previously described (18,19).

H. pylori polymerase chain reaction amplification.—The suspension used for culture was also used for DNA isolation. DNA was isolated using a QIAamp DNA Mini Kit (Qiagen SA, Courtaboeuf, France), according to the manufacturer’s instructions. A real-time polymerase chain reaction (PCR) was performed with a bprobe using the fluorescent resonance energy transfer method on DNA obtained from gastric biopsies (antrum and corpus) to detect H. pylori infection. The method included the specific amplification of a 267-bp fragment of the 23S ribosomal RNA (rRNA) gene of H. pylori with simultaneous detection of the product by probe hybridization and melting curve analysis (20).

RNA Extraction

Gastric biopsy specimens (corpus) were immediately immersed in RNAlater stabilization reagent (Qiagen AG, Basel, Switzerland), then frozen and stored at −20°C. Total RNA was isolated from the gastric biopsy specimen using the RNeasy Mini Kit (Qiagen SA).

Reverse Transcription

The complementary DNA (cDNA) was generated from 1 μg of total RNA using the High-Capacity cDNA Archive Kit (Applied Biosystems, Courtaboeuf, France) with random primers and reverse transcriptase, according to the manufacturer’s protocol.

Real-Time Quantitative PCR

Real-time quantitative PCRs were performed using Assays-on-Demand kits from Applied Biosystems for gene expression products of leptin, ghrelin, and two endogen control genes (i.e., glyceraldehyde-3-phosphate dehydrogenase [GAPDH] and β-actin), designed with the corresponding sequences of the GenBank accession numbers Hs00174497_m1, Hs00175082_m1, Hs9999905_m1, and Hs9999903_m1, respectively. TaqMan Minor Groove Binder probes were synthesized with the reporter dye FAM covalently linked to the 5′P ends and the non-fluorescent quencher (NFQ) at the 3′P ends, which were phosphorylated to prevent probe extension. The Minor Groove Binder moiety is a protein attached to the terminal end of a probe which stabilizes the probe-target complex,
Plasma Leptin and Ghrelin Concentrations

On the same day as the endoscopy took place, blood samples were taken after an overnight fast and stored at −80°C until testing. Plasma leptin and ghrelin concentrations were measured by a commercial radioimmunoassay (RIA) kit (Leptin RIA; Immunotech-Beckman Coulter, Marseille, France and Ghrelin RIA; IBL Immuno-Biological Laboratories, Hamburg, Germany), based on the protocol provided by the manufacturer.

Statistical Analyses

The associations between categorical variables were examined with Fisher’s exact test. Leptin and ghrelin levels were compared for more than two groups by Kruskal–Wallis analysis of variance and between two groups by the Mann–Whitney test. Logarithm transformation was applied to normalize leptin and ghrelin mRNA distribution. An analysis of variance (ANOVA) was used for the assessment of the relationship between leptin and ghrelin levels and age, BMI, energy intake per day, or plasma albumin level. Differences with a p value of less than .05 were considered significant. All statistics were performed using SPSS 12.0F for Windows software (SPSS Inc., Chicago, IL).

RESULTS

Characteristics of the Study Population

Sixty-six patients were initially recruited. All underwent upper gastrointestinal endoscopy as a diagnostic work-up for anorexia (n = 34), chronic anemia (n = 19), or dyspepsia (n = 13). Four patients were not included in the study either because they refused participation or because of poor compliance. The data from 62 patients (18 men and 44 women; mean age: 84.7 ± 5.2 years; range: 75–95 years) were therefore available for analysis. Clinical data of the included patients were collected and showed a mean of 2.4 chronic diseases per patient (range: 0–5): diabetes (8.1%); cardiovascular disease (35.5%), Parkinson disease (9.1%), epilepsy (8.1%), cancer (17.7%), chronic obstructive pulmonary disease (11.3%), dementia (25.8%), and ischemic stroke (19.4%). Creatinine clearance (Cockcroft–Gault equation) was measured for all of the included patients (mean ± SD: 37.1 ± 13.9 mL/min). At endoscopy, a total of 13 (20.9%) patients had no lesions, and 37 (59.7%) patients had an endoscopic diagnosis of gastritis; that is, nonerosive gastritis in 23 patients, and erosive gastritis in 14 patients. Esophageal ulcers were diagnosed in 9 (14.5%) patients. Results of neuropsychological assessment were as follows: Mini-Mental Status Examination: 19.2 ± 6.4, Geriatric Depression Scale (five items): 2.2 ± 1.5. Results of nutritional evaluation were as follows: BMI, 22.5 ± 6.1; energy intake (kcal/day), 911.8 ± 244.1; albumin level, 32.5 ± 6.2 (Table 1). A total of 27 (43.5%) patients had a BMI lower than 21 kg/m² (mean, 18.5 ± 1.8 kg/m²).

Histological Examination

Histological analysis showed the presence of inflammatory lesions in gastric mucosa: 12 patients had inflammatory lesions in the antral part only, 32 had both antral and corpus lesions, and 1 patient had inflammatory lesions in the corpus part only. Histological analysis showed equally high rates of chronic atrophic lesions: 12 patients had atrophic lesions in the antral part only, 18 had both antral and corpus, and 1 patient had corpus lesions only. Patients were considered to be H. pylori-positive when at least one test was positive. A total of 40 (64.5%) patients were H. pylori-positive, and results showed a significant increase in H. pylori infection prevalence with the presence of gastritis. Corpus atrophy was associated with 84.2% H. pylori-positive infection (p = .02), and antral inflammation was associated with 70.5% H. pylori-positive infection (p = .03).

Leptin and Ghrelin Production According to Patient Characteristics

Results showed no variation in ghrelin or leptin levels according to the patient’s clinical characteristics, that is, chronic disease (such as diabetes), cardiovascular dis-
ease, neurological disease, neuropsychological assessment, or creatinine clearance. In contrast, the study of the subgroup of 22 H. pylori–negative patients showed that diabetes was associated with a decrease in gastric ghrelin ($p = .03$).

Leptin and Ghrelin mRNA According to H. pylori Status

To study gastric expression of leptin and ghrelin mRNA levels, real-time PCR was performed on gastric (corpus) biopsy samples. Data were normalized with respect to control genes, that is, GAPDH and β-actin. Relative mRNA quantification of both endogenous genes was positively correlated ($r = 0.73; p < .0001$).

Relative mRNA quantification showed expression of both leptin and ghrelin in corpus biopsy samples of the aging stomach. The presence of H. pylori infection was significantly associated with decreased leptin ($p = .021$) (Figure 1A) and decreased ghrelin ($p = .002$) (Figure 1B) mRNA gastric expression.

Helicoblot was performed on 37 patients and showed seropositivity against CagA in 14 (37.8%). Results showed that gastric ghrelin was expressed at a significantly lower rate in CagA-positive patients ($p = .0001$).

Leptin and Ghrelin mRNA According to Histological Diagnosis

As H. pylori infection was statistically associated with the presence of chronic inflammatory lesions, the relationship between both leptin and ghrelin mRNA gastric expression and severity of histological inflammation was analyzed by using the Kruskal–Wallis test. Results showed a statistically significant association between the severity of corpus inflammation and a decrease in levels of both gastric leptin ($p = .0001$) and ghrelin ($p = .001$) mRNA expression (Table 2).

As a high prevalence of chronic atrophic lesions was present in the study population, the relationship between the mRNA expression of both peptides and the severity of gastric atrophic lesions was also analyzed. Results showed a significant decrease in levels of both gastric leptin (Kruskal–Wallis test, $p = .001$) and ghrelin (Kruskal–Wallis test, $p = .021$) according to the severity of gastric atrophic lesions (Table 2).

### Table 2. Relationship Between Histological Assessment of Gastritis and Ghrelin and Leptin mRNA Gastric Expression

<table>
<thead>
<tr>
<th>Inflammation (corpus)*</th>
<th>Absent (n = 29)</th>
<th>Mild (n = 15)</th>
<th>Moderate to Severe (n = 18)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastric ghrelin (mRNA)$^1$</td>
<td>30304.1</td>
<td>4361.9</td>
<td>345.7</td>
<td>.001$^2$</td>
</tr>
<tr>
<td>Gastric leptin (mRNA)$^1$</td>
<td>28.4</td>
<td>12.8</td>
<td>0.5</td>
<td>.0001$^1$</td>
</tr>
<tr>
<td>Atrophy (corpus)*</td>
<td>Absent (n = 43)</td>
<td>Mild (n = 13)</td>
<td>Moderate to Severe (n = 6)</td>
<td>$p$</td>
</tr>
<tr>
<td>Gastric ghrelin (mRNA)$^1$</td>
<td>22641.7</td>
<td>2654.3</td>
<td>563.5</td>
<td>.003$^1$</td>
</tr>
<tr>
<td>Gastric leptin (mRNA)$^1$</td>
<td>22.3</td>
<td>7.2</td>
<td>0.3</td>
<td>.017</td>
</tr>
</tbody>
</table>

Notes: *Histological analysis according to the Sydney system classification.

$^1$Relative expression of ghrelin or leptin mRNA (median). Data were normalized with respect to control genes, i.e., glyceraldehyde-3-phosphate dehydrogenase (GAPDH) and β-actin.

$^2$Significant association between ghrelin and leptin mRNA levels and the severity of inflammation or atrophic gastric lesions (Kruskal–Wallis test).

mRNA = messenger RNA.
Plasma Leptin and Ghrelin According to H. pylori Status and Histological Diagnosis

Plasma concentrations of leptin and ghrelin were measured in all of the patients included in the study. H. pylori infection was associated with a significant decrease in plasma ghrelin levels ($p = .018$). Plasma ghrelin concentrations tended to decrease in relation to the severity of inflammation (Kruskal–Wallis test, $p = .051$) and atrophic lesions (Kruskal–Wallis test, $p = .063$), but the differences did not reach statistical significance. In contrast, no association between plasma leptin levels and histological parameters was observed.

Nutritional Status According to H. pylori Status

Results showed that H. pylori–positive patients were more frequently at risk of malnutrition than were non-infected patients. In fact, the presence of H. pylori infection correlated negatively with the patient’s BMI ($r = −0.34; p = .018$) (Figure 2A) and with the patient’s energy intake ($r = −0.36; p = .001$) (Figure 2B).

Nutritional Status According to Leptin and Ghrelin Production

Plasma ghrelin concentrations were positively correlated to age ($r = 0.37, p = .04$) and energy intake ($r = 0.4, p = .02$), whereas plasma leptin concentrations were positively correlated to BMI ($r = 0.55, p = .01$). Concerning mRNA gastric expression of these two peptides, no correlation was found between gastric leptin or ghrelin expression and patient’s energy intake ($r = −0.18, p = .21$, and $r = −0.21, p = 0.16$, respectively), and patient’s BMI ($r = 0.2, p = .17$, and $r = 0.16, p = .27$, respectively).

Discussion

To our knowledge, this study is the first investigation of gene expression of leptin and ghrelin in the aging stomach. We demonstrated decreased gastric mRNA expression of both peptides as a function of gastritis associated with H. pylori infection in patients older than 75 years. In our study, even if it was not possible to see the outcome after H. pylori eradication, a significant decrease in nutritional parameters among infected patients was found. In fact, the presence of H. pylori infection was associated with lower BMI and energy intake. One of the possible mechanisms to explain these results could be the variations in leptin and ghrelin, which are secondary to chronic H. pylori gastritis. Indeed, recent studies reported variations in the production of leptin and ghrelin in gastric mucosa in the case of H. pylori infection, that is, enhanced production of gastric leptin and decreased production of gastric ghrelin (21,22).

Azuma and colleagues (23) demonstrated that H. pylori infection significantly increased gastric leptin mRNA expression and that cure of the infection significantly reduced it. Nishi and colleagues (21) also reported a significantly positive correlation between gastric leptin and mucosal concentrations of interleukin-1β and interleukin-6. The authors explained that locally released leptin may be implicated in the immune and inflammatory responses to H. pylori, through interaction with proinflammatory cytokines. A positive correlation of gastric leptin with scores of chronic inflammation was also reported. Our data in elderly patients show contradictory results, that is, H. pylori chronic gastritis induced a significant decrease in production of gastric leptin mRNA, which was dependent on the severity of inflammatory gastric lesions. These contradictory results may be explained by the high prevalence of atrophy in our

Figure 2. Correlation between Helicobacter pylori infection and nutritional status (body mass index [BMI], kcal intake). The units shown are therefore referred to as “normalized mRNA levels.” A, Negative correlation between H. pylori infection and BMI (kcal/m$^2$) ($r = −0.34; p = .018$). B, Negative correlation between H. pylori infection and energy intake (kcal/day) ($r = −0.36; p = .001$).
population. The decrease of leptin mRNA gastric expression was significantly associated with grading scores of atrophy, mRNA levels of gastric leptin decreased according to the severity of gastric atrophic lesions. During the process of atrophy, the leptin mRNA–producing cells are more likely to disappear, whereas in previous studies carried out on younger populations, atrophy was probably not as common. The subpopulation of patients without atrophy was indeed too small to produce meaningful results. Further investigations are needed to explain these results. In contrast, concerning plasma leptin levels, our results did not find any variation according to either H. pylori status, or inflammatory and atrophic grades in gastric mucosa. This is in agreement with some authors who reported no variation in plasma leptin concentrations in H. pylori–positive patients, even after successful eradication (21,23). However, in another study, a significant decrease in plasma levels of leptin was noted after H. pylori eradication (24). Our result may suggest that adipose tissue is the main contributor to circulating leptin. The positive correlation found in our study between plasma leptin levels and patient BMI militates for this interpretation. In fact, leptin is known to be highly correlated with total fat mass in humans. Leptin is considered to be a peripheral signal of energy status rather than a satiety signal. Appetite is regulated by both a peripheral signal of energy status (such as leptin) and satiety (gut hormones, such as ghrelin) that alter neuronal activity within the hypothalamus, and thus influence feeding and energy intake (25).

Concerning gastric ghrelin production, most of the studies reported a decreased production in infected patients. Osaka and colleagues (22) showed that the expression levels of ghrelin mRNA and the number of ghrelin-producing cells in the gastric mucosa were much lower in patients with H. pylori infection. Tatsuguchi and colleagues (26) reported similar results with a significant increase in ghrelin gastric production following H. pylori eradication. Our results are in agreement with those data, with a significant decrease in ghrelin production in infected patients. We also reported a significant decrease in gastric ghrelin production in relation to the severity of inflammation, and according to the severity of atrophy for leptin gastric production, a significant decrease in gastric ghrelin production (in chronic atrophic gastric lesions). Very few results are available in the literature on this topic. Isomoto, Nwokolo, and colleagues (27–29) recently reported that chronic atrophic lesions caused impairment of gastric ghrelin biosynthesis. Most of the data concerned plasma ghrelin levels, and reported a significant decrease in plasma ghrelin levels based on the histological grades of corpus glandular atrophy and serum pepsinogen I/II ratios in H. pylori-positive patients. Our results, concerning plasma ghrelin concentrations, also demonstrate a significant decrease in plasma ghrelin levels in H. pylori-positive patients, with a tendency for plasma ghrelin levels to decrease in relation to the presence of gastric atrophic lesions. We suggest that the decrease in ghrelin production in the gastric mucosa accounts for the decrease in the plasma ghrelin concentrations in H. pylori-positive patients. Some authors suggested that enhanced gastric ghrelin production observed after H. pylori eradication accompanied by an increased 24-hour gastric acidity may be secondary to parietal cell recovery (30).

We looked for the relationship between ghrelin levels and the patient characteristics, that is, chronic disease. Our results did not show any variation of ghrelin levels according to the patient’s chronic disease. Many recent studies reported that ghrelin had important effects, including effects on gastric motility and acid secretion, but also on sleep and the cardiovascular system (i.e., the elevation of plasma ghrelin may play a role in seizure occurrence via its effects on GHs, and ghrelin may induce an increase in cardiac index as well as a decrease in mean arterial pressure) (31,32). As the presence of chronic H. pylori gastritis was associated with a lower production of ghrelin, we chose to study ghrelin variation in the subgroup of H. pylori–negative patients. Our results showed a significant decrease in gastric ghrelin production in patients with diabetes. These results were also reported in animal studies, and the authors concluded that the reduced density of ghrelin-immunoreactive cells in animal models of human diabetes types 1 and 2 may explain the slow gastric emptying and the slow intestinal transit found in diabetes gastroenteropathy (33).

We measured the total ghrelin concentration containing both acyl-modified and desacyl ghrelin for all of the included patients. Ghrelin owes its biological activity to the acylation of its third serine. Quickly desacylated, ghrelin circulates both as an acylated active form and a desacylated inactive form, together representing the total amount of ghrelin. Because of a lack of a ghrelin active-specific immunoassay, almost all of the published work on humans focused on total ghrelin, which presents the major disadvantage of reflecting not only the active hormone but also its inactive catabolite.

Our results showed a positive correlation between circulating ghrelin and energy intake. Ghrelin has been considered to be an appetite stimulatory signal that reaches the arcuate nucleus of the hypothalamus via the bloodstream. Ghrelin activates orexigenic peptides, that is, neuropeptide Y and agouti-related peptide whereas neurons containing the anorexigenic peptides (i.e., cocaine- and amphetamine-related transcripts and pro-opiolamnocortin) are inhibited. The increased appetite will result in increased food intake and an increase in body weight, however, our results did not show any association between ghrelin levels and patient BMI. Whether diminished ghrelin gastric production causes weight loss is not clear (34). Facts cannot be disproved. The fact is that H. pylori infection does decrease the ghrelin level, but it remains to be proven that changes in ghrelin levels influence body weight in humans. Limitations of this study include its descriptive design, use of small and heterogeneous sample, and lack of follow-up after H. pylori eradication. In fact, only hospitalized elderly patients could be included in this study because of ethical reasons, and no case–control design was than realizable.

Conclusion

The presence of H. pylori chronic gastritis induced a decrease in both leptin and ghrelin gastric production in frail elderly patients, which may in fact be due to the high
prevalence of atrophic lesions observed in this particular population. The presence of *H. pylori* chronic gastritis induced a lower energy intake and BMI in these elderly patients, and was associated with lower circulating ghrelin. Further investigations are needed to better understand the role of these gastric satiety inducible peptides in aging anorexia, especially after *H. pylori* eradication.

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