ORIGINAL ARTICLE

A double-blind placebo-controlled randomized trial on probiotics in small bowel bacterial overgrowth in children treated with omeprazole☆

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KEYWORDS
(Hydrogen) breath test;
Diarrhea;
Flatulence;
Omeprazole;
Probiotic;
Proton pump inhibitor;
Small bowel bacterial overgrowth

Abstract
Objective: To evaluate the incidence of small bowel bacterial overgrowth (SBBO) in children treated with omeprazole, and to test whether probiotics influence the incidence.
Methods: A double-blinded, placebo-controlled trial was performed in 70 children treated orally during four weeks with 20 mg omeprazole per day. Lactobacillus rhamnosus R0011 (1.9 × 10^9 cfu) and Lactobacillus acidophilus R0052 (0.1 × 10^9 cfu) were simultaneously given daily to 36 subjects (probiotic group), while 34 subjects received placebo (placebo group). The diagnosis of SBBO was based on the development of suggestive symptoms, in combination with a positive glucose breath test.
Results: After one month of proton pump inhibitor (PPI) treatment, 30% (21/70) had a positive breath test suggesting SBBO; of these 62% were symptomatic. Five children developed SBBO-like symptoms, but had a negative breath test; and 44 (63%) were symptom free and had a negative breath test. There was no difference in the incidence of positive breath tests in the probiotic versus the placebo group (33% vs 26.5%; p = 0.13).
Conclusions: Since symptoms suggesting SBBO developed in 26% of PPI-treated children, and since the glucose breath test was abnormal in 72% of these, this side-effect should be more frequently considered. The probiotic tested did not decrease the risk to develop SBBO.
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Introduction

Proton pump inhibitors (PPIs) such as omeprazole are administered in gastrointestinal diseases such as gastroesophageal reflux disease, gastric or duodenal ulcer, Zollinger-Ellison syndrome, and eradication therapy for Helicobacter pylori. The gastric acid secretory inhibitor effect of PPIs is much more potent than the effect of histamine receptor antagonists.

Small bowel bacterial overgrowth (SBBO) is a condition marked by an increased number of intestinal bacteria and a change in bacterial composition in the gastrointestinal tract. Risk factors for SBBO are long term hypo/achlorhydria (as induced by PPI), intestinal anatomical abnormalities (such as diverticulum, fistula, stricture, adhesion, removal of ileocecal flap), hypomotility (such as in diabetic neuropathy, scleroderma), and severe immunodeficiency. The diagnosis of SBBO is based on clinical manifestations and on the results of a glucose breath test. Clinical manifestations of SBBO are marked by symptoms such as abdominal pain, flatulence, frequent flatus, diarrhea or constipation, and steatorrhea. In chronic conditions, SBBO can cause anemia, failure to thrive, neuropathy, tetany, and paresthesia. The golden standard to diagnose SBBO is to culture intestinal aspirate. However, the latter is not performed in routine practice because of its invasive nature, its difficulty, its relatively high cost and time consumption, and its inability to diagnose SBBO in the distal area of the intestine. The Rome Consensus of 2009 recommended the glucose hydrogen breath test as the best diagnostic tool for SBBO, since it is non-invasive, easy to perform, has direct results, and has a good diagnostic accuracy.

Probiotics are living microorganisms which, if ingested in adequate amounts, will result in a health benefit for the host. A role for probiotics in many diseases such as infectious diarrhea, antibiotic associated diarrhea, atopy, and constipation has been suggested. Efficacy has also been reported for some strains, such as Lactobacillus shinrota, in SBBO. Probiotics’ mechanisms of action consist of competition with harmful bacteria, synthesis of antimicrobial conjugate (bacteriocin, lactic acid, organic acid, microcin, reuterin, and volatile fatty acid), stimulation of the immune response, and stimulation of the intestinal epithelium through production of short chain fatty acids. Until now, studies on the role of probiotics in prevention and therapy of SBBO in children are very limited.

The aims of this study were to test whether PPIs induce SBBO in children, and to evaluate whether the probiotic strains tested can prevent the development of SBBO.

Methods

Study design and subjects

This double-blinded, placebo-controlled randomized clinical trial was conducted in children ≥ 5 years old seen mainly because of complaints of epigastric pain in the Outpatient
Clinic of the Cipto Mangunkusumo Hospital. When it was
decided, on clinical grounds, that the presenting symptoms
justified a therapeutic trial with omeprazole, and in
the absence of exclusion criteria, a glucose breath test was per-
formed to rule out SBBO prior to PPI-therapy.

All the subjects were treated with 20 mg of oral omep-
razole daily for four weeks. Patients swallowed the intact
omeprazole capsule; patients with difficulties to swallow
the capsule were allowed to open it and swallow the micro-
granules in media such as orange juice or berry juice.
Furthermore, the patients were randomized in two groups:
group A (probiotic group) received one probiotic capsule per
day during four weeks, while group B (control group) was
given a placebo capsule. The probiotic used is Lacidofil®,
which contains $1.9 \times 10^8$ cfu Lactobacillus rhamnosus R0011
and $0.1 \times 10^9$ cfu Lactobacillus acidophilus R0052. A cold
chain for the administration of the probiotic was preserved,
as the probiotics were stored in a cooler and transported
using a cold chain bag with gel ice packs inside.
The following patients were excluded: known SBBO;
treatment with anti-acid agents or antibiotics during the
past two weeks; immune suppression (steroid treatment,
antituberculosis therapy, antiretroviral, or cytostatics); or
warfarin, phenytoin or diazepam use.

Observation for medication compliance (PPI and pro-
biotic/placebo) was performed twice a week through phone,
by asking the parents about compliance. Subjects who did
not take their medication during at least three days during
the four-week intervention period were considered as "poor
compliant". A second glucose breath test was performed
four to ten days after the end of therapy.

Hydrogen breath test$^8,9,20$

The patients fasted for ten to 12 hours, and brushed their
teeth in the morning prior to the examination. The breath
test started by measuring the baseline hydrogen; the latter
had to be < 10 ppm to be considered as normal (Gastrolyzer2,
Bedfont Scientific Ltd.; distributor for Indonesia: CV Andalan
Batar, Jakarta). A normal baseline hydrogen value was neces-
sary to be eligible for inclusion. The patients ingested
2 g/kg body weight glucose (maximum of 50 g), which was
diluted in 10 mL/kg body weight water (maximum 250 mL).
The hydrogen level was measured every 15 minutes up to two
hours after ingestion of the glucose. Every clinical symptom
or complaint during the breath test was recorded. A posi-
tive breath test was defined as an increase of > 10 ppm from
baseline.$^{21}$

Patients, parents, and all study participants were
blinded. Study evaluators were blinded by omission of the
name of patient on the hydrogen breath test data. The
placebo was made by the Pharmacy Department of the Fac-
ulty of Medicine of the University of Indonesia.

Statistical analysis was performed with the Statistical
Package for Social Sciences (SPSS) version 17. The proto-
col was approved by the local ethical committee, and all
parents signed an informed consent.

Results

Initially, 73 patients were included in the study. However,
home visits found that three patients did not have a refrig-
erator at home. Since it was not known whether they were
in the probiotic or the placebo group, and since the probi-
totic needed to be conserved in a cool environment, these
patients were considered as dropout. Thus, data of 70
patients were available for analysis. Most of the subjects
were female (61/70), with a good nutritional status (39/70)
(Table 1).

The mean age was 13.5 years (range 6-17 years). Of the
70 subjects, 36 were included in the probiotic and 34 in the

<table>
<thead>
<tr>
<th>Characteristics of subjects</th>
<th>Group</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probiotics</td>
<td>Placebo</td>
</tr>
<tr>
<td><strong>Age (years)$^a$</strong></td>
<td>13.5</td>
<td>14</td>
</tr>
<tr>
<td>Median</td>
<td>6-17</td>
<td>12-17</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender$^b$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Female</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td><strong>Nutritional status$^c$</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good (CDC Curve, BW/BL &gt; 90%-100%)</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>Undernourished (CDC Curve, BW/BL 70%-90%)</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Overweight (BMI &gt; P85)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Obese (BMI &gt; P95)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

BMI, body mass index; BW/BL, birth weight/birth length; CDC, Centers for Disease Control and Prevention.

$^a$ Mann-Whitney test.

$^b$ Fisher’s exact test.

$^c$ McNemar’s test.
placebo group. Medication compliance was rather low since "good compliance" was only observed in 41/70 patients (59%). Compliance was "poor" in 29 patients; 11 complied poorly with the probiotic or placebo, and 18 complied poorly with the PPI. Nevertheless, 66/70 (94%) of the patients said to be symptom-free or to have a clinically significant improvement of their symptoms after the intervention. Only 4/70 (6%) said to have not improved.

In total, 18 subjects developed symptoms suggesting possible SBBO; in 13 of these, the second breath test suggested SBBO. 16 of these 18 patients had a "good PPI compliance". According to the results of the breath test (regardless of the presence/absence of symptoms), SBBO was found in 21/70 (30%) of the patients, with a slight trend of more SBBO in the probiotic group (33%; 12/36) than in the placebo group (26%; 9/34) (p = 0.13, Table 2). From the 21 subjects with positive hydrogen breath test, 13 subjects presented recurrent SBBO symptoms during therapy (Table 3), while eight were asymptomatic. Finally, 44/70 (63%) patients were asymptomatic and had a negative glucose breath test under PPI treatment. Five patients had symptoms suggesting SBBO, but had a normal breath test result. 13/21 (62%) developed at least one symptom compatible with SBBO during PPI therapy; four (19% of the total group, or 31% of the symptomatic group) presented more than one symptom (Table 4). Two subjects developed extensive SBBO with diarrhea, abdominal pain, and flatulence.

Discussion

This was the first study conducted in children that focused on SBBO incidence with PPI treatment as single risk factor, and also evaluated the role of probiotics in prevention of SBBO. The results suggest a placebo-effect of the PPI, since 18/70 were not compliant; only four reported no significant improvement, all of which in the non-compliant group. A cohort study by Boissieu et al. in 53 children, aged between 2 months and 12 years, with complaints of chronic diarrhea, abdominal pain, or both, reported SBBO as a frequent cause (34%), especially before the age of 2 years. Scarpellini et al. reported the prevalence of SBBO to be as high as 65% in children aged 3 to 16 years with irritable bowel syndrome (IBS). Ratuapli et al. published recently a large retrospective analysis on the effect of PPI on SBBO in adults. Overall, the authors reported that PPI did not induce SBBO;

Table 2 Hydrogen breath test results related to probiotic or placebo, regardless of symptoms.

<table>
<thead>
<tr>
<th></th>
<th>SBBO</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Omeprazole + probiotics</td>
<td>12 (33%)</td>
<td>24 (67%)</td>
</tr>
<tr>
<td>Omeprazole + placebo</td>
<td>9 (26%)</td>
<td>25 (73%)</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>49</td>
</tr>
</tbody>
</table>

p = 0.13.
SBBO, small bowel bacterial overgrowth.

Table 3 Number of children with symptoms suggesting small bowel bacterial overgrowth (SBBO) and result of the second glucose hydrogen breath test.

<table>
<thead>
<tr>
<th>Symptoms suggesting SBBO</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result H2 breath test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Negative</td>
<td>5</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>52</td>
</tr>
</tbody>
</table>

p < 0.001 (chi squared test).

Table 4 Complaints and therapy response.

<table>
<thead>
<tr>
<th>Characteristics of subjects</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial complaints</td>
<td></td>
</tr>
<tr>
<td>Epigastric pain</td>
<td>70 (70/70)</td>
</tr>
<tr>
<td>Nausea</td>
<td>65 (65/70)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>10 (10/65)</td>
</tr>
<tr>
<td>Gastrointestinal bleeding</td>
<td>3 (3/10)</td>
</tr>
<tr>
<td>Flatulence</td>
<td>30 (30/70)</td>
</tr>
<tr>
<td>Limitation of activity</td>
<td>45 (45/70)</td>
</tr>
<tr>
<td>Medication compliance</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>41 (41/70)</td>
</tr>
<tr>
<td>No</td>
<td>29 (29/70)</td>
</tr>
<tr>
<td>Therapy response</td>
<td></td>
</tr>
<tr>
<td>Cured</td>
<td>46 (46/70)</td>
</tr>
<tr>
<td>Improvement</td>
<td>20 (20/70)</td>
</tr>
<tr>
<td>No improvement</td>
<td>4 (4/70)</td>
</tr>
<tr>
<td>SBBO symptoms during therapy in groups with positive hydrogen breath test</td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td>1 (1/21)</td>
</tr>
<tr>
<td>Mid abdominal pain</td>
<td>1 (1/21)</td>
</tr>
<tr>
<td>Flatulence</td>
<td>5 (5/21)</td>
</tr>
<tr>
<td>Frequent flatus</td>
<td>1 (1/21)</td>
</tr>
<tr>
<td>Constipation</td>
<td>1 (1/21)</td>
</tr>
<tr>
<td>Flatulence and abdominal pain</td>
<td>2 (2/21)</td>
</tr>
<tr>
<td>Diarrhea, flatulence, and abdominal pain</td>
<td>2 (2/21)</td>
</tr>
<tr>
<td>No complaints</td>
<td>8 (8/21)</td>
</tr>
</tbody>
</table>

SBBO, small bowel bacterial overgrowth.

* Complaints of vomiting mixed with brown spots.
HBT-positivity was associated with older age and use of antidiarrheal products. However, Del Piaano almost simultaneously confirmed a strong bacterial overgrowth in the stomach and duodenum of adults treated with PPI, increasing with treatment duration. The glucose breath test at baseline was normal in all children included in the present study.

In the present study, the subjects involved were children with a mean age of 13.5 years, who presented with the single chief complaint of epigastric pain. The proportion of girls in this study was much higher than boys, but gender was normally distributed in both groups ($p = 1.00$). This difference can be explained by coincidence, by the fact that there are more girls than boys in this age group in Jakarta, and/or by the fact that functional gastrointestinal complaints might be more frequent in girls. However, this striking difference needs further investigation.

Sixty-two percent of the subjects with positive hydrogen breath test developed SBBO symptoms during therapy and during the breath test (Tables 2 and 3). This is in agreement with studies in children, which have showed SBBO to be a common cause of abdominal pain and diarrhea in children. 16 of 18 children with SBBO symptoms had a "good compliance to PPI", reinforcing the argument of PPIs as a cause of SBBO. To the authors' knowledge, studies on SBBO incidence in children related to omeprazole therapy have not been performed; however, this incidence was reported to be as high as 45% to 56% in adult subjects. The difference in SBBO incidence in the present study (19%) with that of the adult studies can be explained by several factors, such as difference in dosage and duration of omeprazole treatment, different characteristics of the patients, and different diagnostic methods. This differs from the characteristics of adult studies, in which the mean age of the patients is over 50 years. SBBO incidence is higher later in life due to the decline in immunity and intestinal motility, as well as hypo/achlorhydria. The incidence of SBBO and hypo/achlohydria in a senior age group (mean age 84 years) was reported to be 80%. The high metabolism of omeprazole in certain age ranges (between 1 and 6 years and 13 and 16 years), which is in line with the subjects' age in this study, may contribute to the lower incidence of SBBO in adolescents.

The duration of omeprazole therapy is directly related with SBBO incidence. This finding is also supported by a study by Lombardo et al., which showed that SBBO incidence is significantly higher in the group with PPI therapy for over 13 months ($p < 0.001$). In the present study, SBBO incidence was evaluated in children treated with 20 mg of omeprazole daily for four weeks. The dosage and duration of therapy is smaller in the present study than in the reports in adults using 20 to 40 mg of omeprazole for ≥4 weeks, up to 9.5 months.

The probiotic strains administered did not decrease the development of SBBO. However, probiotics are a therapeutically option of potential benefit. Lactobacillus shirata was shown to be effective in altering fermentation patterns in the small bowel, consistent with SBBO reduction. Del Piano et al. demonstrated that four probiotic strains with a marked antagonistic activity towards five $E. coli$ bacteria and an effective amount of N-acetylcysteine (NAC) reduced bacterial overgrowth in long-term PPI-treated subjects. A significant decrease in fecal enterococci, total coliforms, $E. coli$, molds, and yeasts in subjects treated with PPIs was recorded at the end of the probiotic supplementation.

The hydrogen breath test measures the amount of expired hydrogen in the expired air after fasting for ten to 12 hours, followed by ingestion of glucose substrate. If the glucose is not absorbed, but metabolized by intestinal bacteria, intraluminal gasses such as hydrogen ($H_2$), methane ($CH_4$), and carbon dioxide ($CO_2$) will be produced, which can be measured by the breath test. The glucose hydrogen breath test is reported to have a sensitivity, specificity, and diagnostic accuracy of 62.5%, 81.8%, and 71.7%, respectively. According to the Rome consensus of 2009, the glucose hydrogen breath test is the recommended diagnostic tool in patients with suspected SBBO.

In the present study, five subjects developed SBBO-like symptoms but had a negative hydrogen breath test. The glucose breath test can be false negative due to intestinal colonization with non-hydrogen producing bacteria, or because the level of hydrogen production is not high enough to be detected, and SBBO is occurring in the distal part of ileum (where all the glucose has already been absorbed). According to literature, the prevalence of colonization with non-hydrogen producing bacteria varies from 2% to 43%. However, non-hydrogen producing bacteria produce methane, resulting in an increase of expired methane despite normal hydrogen. Levit et al. reported that 36.4% of adults (aged 18 to 88 years) with SBBO had a methane-producing gastrointestinal colonization. Since the device used in the present study only measures hydrogen and not methane, further information on this aspect cannot be provided. In some patients, SBBO-related symptoms are similar to the initial presenting symptoms. Although it cannot be excluded that in a few patients it was the initial symptoms that persisted, this is unlikely for different reasons: i) the initial symptoms had strong improvement; ii) symptoms were reported as being different; iii) there was an association with the positive breath test. Moreover, 16 of 18 children with symptoms suggesting SBBO were compliant to PPI treatment. The second breath test was performed four to ten days after stopping PPI therapy, when the potential acid rebound secretion period caused by PPI interruption was over.

In conclusion, SBBO was found to be frequent in children treated with 20 mg/day of omeprazole for four weeks (26% if only symptoms are considered; 30% if only results of hydrogen breath test are considered; 19% if both symptoms and positive hydrogen breath test are considered). The probiotic tested did not prevent the development of SBBO. Children who develop symptoms such as diarrhea, abdominal pain, and flatulence under PPI treatment should be investigated for SBBO.

Funding

Dexa Medica provided free samples of the probiotic and placebo.
Conflicts of interest

YV is a consultant for Biocodex and United Pharmaceuticals. The other authors declare no conflicts of interest.

References


