Inhibitory actions of a high fibre diet on intestinal gas transit in healthy volunteers

S Gonlachanvit, R Coleski, C Owyang, WL Hasler

Background: Fibre treatment often produces gaseous symptoms which have been attributed to fermentation by colonic bacteria with increased gas production. Effects of fibre ingestion on intestinal gas flow are unexplored.

Aims: We aimed to test the hypothesis that consumption of a high fibre diet retards gas transit.

Subjects: Ten healthy volunteers participated.

Methods: To investigate the effects of fibre on gas dynamics, physiological gas mixtures were jejunally perfused at 12 ml/min × 2 hours after a standard diet for seven days with and without psyllium 30 g/day in a crossover fashion. Gas was collected from an intra rectal catheter to bypass the anus and evacuation was quantified in real time using a barostat.

Results: On initiating gas perfusion under control conditions, an initial lag phase with no gas expulsion was observed (1129 (274) seconds). Thereafter, gas evacuation from the rectum proceeded with cumulative volumes of 1429 (108) ml by the end of the second hour. Evacuation was pulsatile with passage of 20.9 (2.5) boluses, with mean volumes of 58.2 (5.0) ml. Fibre prolonged the lag time (2265 (304) seconds; p < 0.05) and reduced cumulative gas evacuation volumes (1022 (80) ml; p < 0.05). Decreased gas evacuation resulted from reductions in the numbers of bolus passages (14.2 (1.1); p < 0.05) but not bolus volumes (70.7 (3.4) ml; p = 0.66).

Conclusions: Consumption of a high fibre diet retards intestinal gas transit by decreasing bolus propulsion to the rectum. Thus, in addition to increasing gas production by colonic flora, fibre ingestion may elicit gaseous symptoms by promoting gas retention.

Increased fibre consumption is advocated for patients with constipation. Fibre has other beneficial effects, including reducing serum cholesterol, preventing colon cancer, decreasing faecal incontinence, relieving symptoms from diverticulosis, and improving glycaemic control in diabetics.

Materials and methods

Test subjects

Ten healthy volunteers (eight males, two females; aged 19–46 years) with no history of gastrointestinal symptoms, no prior gastrointestinal surgery, and on no medications known to alter gut motor function or transit were recruited through campus wide advertisement. Each subject gave written informed consent before entering the study. Women of child bearing potential underwent serum pregnancy testing prior to enrolment. All studies were approved by the University of Michigan Medical Center Institutional Review Board.

Study design

All subjects underwent two gas dynamic studies, each after a seven day period on a standard diet (subjects’ usual diets) or a standard diet supplemented with psyllium 10 g three times daily with each meal (total daily psyllium intake 30 g) in a crossover fashion at least seven days apart in random order. Volunteers fasted overnight and reported at 7:30am on each study day. Subjects underwent initial rectal evacuation with a 500 ml water enema. A silicone rubber catheter with an outside diameter of 4.2 mm and a 1.9 × 2.4 mm central lumen open at its tip (Dentsleeve Pty Ltd, Wayville, SA, Australia) was passed using fluoroscopy with positioning of the tip 5 cm distal to the ligament of Treitz for gas perfusion. A 24 Fr Foley catheter was inserted into the rectum for gas collection. The subject was placed in a quiet room and lay supine at a 30°
incline for a 30 minute equilibration period prior to initiation of gas perfusion.

**Jejunal gas perfusion**

A gas mixture containing 88% nitrogen, 6.5% carbon dioxide, and 5.5% oxygen was perfused into the jejunum at a rate of 12 ml/min. The technique has been previously validated. This mixture of gases approximates concentrations in venous blood and thus has been termed physiological. Furthermore, there is no significant gas reflux into the stomach and 95% of perfused gas is recovered in the rectum. Gas perfusion was controlled by a digital mass flow controller (Brooks Smart Mass Flow Controller, Model 5850S; Brooks Instrument, Hatfield, Pennsylvania, USA) which served to pump the gas mixture into the jejunum at the predetermined fixed rate of 12 ml/min. Flow entering the jejunum was monitored by a digital mass flowmeter (Brooks Smart Flow Meter, Model 5860E; Brooks Instruments) which continuously measured the rate of gas perfusion into the jejunum and served as a control to confirm that the desired flow rate was maintained at 12 ml/min at all times. The mass flow controller and the mass flowmeter were interfaced with a personal computer (Dimension 8200; Dell Inc., Round Rock, Texas, USA) via a digital converter (USB Data Acquisition Function Module; Data Translation Inc., Marlboro, Massachusetts, USA). Rates of gas perfusion were set and monitored using Data Acquisition Software version 1.0 (Data Translation Inc.).

**Quantification of evacuated gas**

Evacuated gas collected from the rectal catheter was connected to low resistance, low compliance tubing and was measured by a barostat (Isobar III; G&J Electronics, Hamilton, Ontario, Canada) which was controlled by Protocol Plus Software (G&J Electronics). Prior to the study, the barostat was emptied and the pressure was set at 0 mm Hg with a sensitivity of 0.3 mm Hg and a maximum flow rate of 35 ml/s. Any gas flow generating a pressure >0.3 mm Hg was collected into the barostat. Volumes and pressures of gas collected in the barostat were recorded at a sampling frequency of 1 Hz over the two hour perfusion period for subsequent analysis.

**Intestinal gas dynamic parameters**

After an initial lag period, gas was evacuated from the rectum either as bolus movements or as continuous flow during jejunal gas perfusion. The lag period was defined as the time from initiation of gas perfusion to the first passage of >20 ml of gas from the rectum. Bolus movements were defined as passages >10 ml in volume at a rate >2 ml/s with an interval between movements >10 seconds, regardless of the pressure of the gas movement. Volume, duration, and peak pressure for each bolus movement were determined as shown in fig 1. The flow rate for each bolus movement was calculated by dividing the bolus volume by its duration. Continuous flow was defined as any volume of gas evacuated in a given time that did not exhibit a discrete passage of 10 ml and that occurred at a rate <2 ml/s. Inspection of evacuation profiles during periods of continuous flow revealed slow linear gas volume expulsions lasting 1–3 minutes without abrupt changes in volume or pressure. These slow linear gas expulsions were not secondary to leaks in the system as continuous flow rates varied during individual recording sessions and included recording segments in which no gas was evacuated. The total gas volume evacuated during jejunal perfusion was calculated as the sum of bolus and continuous gas flow volumes.

**Figure 1** Sample pressure (A) and volume (B) tracings from the barostat are shown during a bolus gas evacuation from the rectum. (A) Peak bolus pressure is defined as the pressure difference between maximal pressure and baseline pressure. (B) Bolus volume and duration are displayed. Bolus volume is the volume difference between the volume before and after gas evacuation. Bolus duration is the time needed for 90% of the bolus volume to be evacuated.

**Figure 2** Sample gas evacuation profiles are shown for a healthy individual after seven days on a standard diet (A) and seven days on a standard diet supplemented with psyllium (B). In each case, gas evacuation is pulsatile with passage of discrete boluses (arrows) after a lag period after initiation of jejunal gas perfusion during which time no gas expulsion occurs. The tracing on the high fibre diet is characterised by passage of fewer gas boluses after a more prolonged lag phase than on the standard diet.
**Statistical analysis**

All results are expressed as mean (SEM). Intestinal gas dynamic parameters, including lag times to first evacuation, bolus volume, bolus pressure, bolus flow rate, and continuous flow rate were compared using two tailed Student’s paired t testing on the standard diet and the standard diet supplemented with psyllium. Repeated measures ANOVA was employed to compare gas retention and bolus evacuation numbers as a function of time on the two diets. A p value <0.05 defined statistical significance.

**RESULTS**

All volunteers completed both perfusion studies after ingestion of a standard diet and a standard diet supplemented with 30 g of psyllium for seven days. Representative gas evacuation profiles for one volunteer on each diet are shown in fig 2. On a standard diet, evacuation was predominantly pulsatile in nature and proceeded after a lag period in which no expulsion occurred. With ingestion of the fibre supplemented diet, evacuations also occurred in bolus fashion which occurred after a more prolonged lag phase of no expulsion.

**Comparison of diet effects on gas evacuation**

The fibre supplemented diet had pronounced effects on several parameters related to gas expulsion and retention. The lag time from initiation of perfusion to the first rectal gas expulsion was prolonged on the high fibre diet compared with the standard diet (p<0.05) (fig 3). Nine of 10 volunteers exhibited a longer lag phase on the diet supplemented with psyllium. Conversely, there was a significant decrease in the total gas evacuated on the fibre supplemented diet versus the standard diet (p<0.05) (fig 4). Gas retention was calculated by subtracting cumulative gas expelled from the rectum from cumulative gas perfused in the jejunum. Because of the longer lag phase, gas retention was significantly greater on the high fibre diet compared with the standard diet during the initial perfusion period and was significantly greater than that occurring after ingestion of the standard diet (p<0.05). Results are mean (SEM), n = 10.

**Characterisation of gas evacuation profiles**

Effects of fibre on cumulative gas flow resulted primarily from effects on bolus evacuations from the rectum. Only small amounts of gas were expelled in a continuous fashion, not as part of a bolus. Continuous expulsion was not different on a standard diet (0.6 (0.3)%) and a diet supplemented with psyllium (1.8 (0.6)%) (p = 0.17). Total numbers of evacuations were lower on a fibre supplemented diet versus the standard diet (p<0.05) (fig 6A). To subtract the effects of the lag phase, numbers of boluses per 30 minutes after completion of the lag phase were calculated. After excluding the lag phase, rates of bolus expulsion were decreased on the high fibre diet compared with the standard diet (p<0.05) (fig 6B). Furthermore, bolus expulsion rates as a function of time demonstrated greater numbers of evacuations in each
of gas flow during each bolus and bolus durations were unaffected by fibre ($p = 0.27$ and $p = 0.66$, respectively) (Table 1). Similarly, volumes and pressures of each bolus were similar on the fibre supplemented and standard diets ($p = 0.66$ and $p = 0.72$, respectively) (Table 1).

### DISCUSSION

Beneficial effects of fibre include relieving constipation in IBS, reducing serum cholesterol, decreasing the risk of colonic neoplasia, and improving glycaemic control in diabetes. Bloating, flatulence, and eructation are prominent complaints of many IBS patients. Studies have shown that fibre exacerbates rather than relieves gaseous complaints in IBS. In an uncontrolled investigation, bran worsened symptoms in 55% of patients but provided benefits in only 10%. Other controlled trials of bran have reported increases in bloating and gas in IBS compared with placebo.

It is not known why fibre increases gaseous complaints. Studies have shown correlations between fibre intake and daily flatus emissions. Most fibre compounds are comprised of complex carbohydrates. Complex carbohydrates in dietary wheat, oats, and potatoes increase production of hydrogen and other gases. Similarly, guar increases colonic methane production. Although they are partially fermented, psyllium and ispaghula husks do not promote gas generation by gut flora, indicating that mechanisms other than bacterial fermentation elicit gaseous symptoms during fibre therapy.

Investigations of fibre effects on non-gaseous luminal transit provide conflicting results. Bran accelerates colonic transit of stool whereas psyllium has variable effects on stool propulsion. Effects of fibre on small intestinal transit of meal residues are largely unexplored. One report noted more prolonged small bowel transit of bran than lactulose but this may have been secondary to the propulsive effects of lactulose rather than an inhibitory action of the fibre.

The present investigation is the first rigorous analysis of the effects of fibre on transit of intestinal gas. In this study, psyllium retarded expulsion of jejunally perfused physiological gas mixtures. Most prominently, fibre prolonged the lag time from initiation of gas perfusion to the first gas expulsion and promoted gas retention which was most significant in the initial hour of the study. Moreover, after completion of the lag phase, gas expulsion proceeded at a reduced rate on a fibre supplemented diet compared with that observed on a standard diet. At the end of the study, gas retention was pronounced on the high fibre diet whereas little gas was retained on the standard diet. There were no differences in the properties of each individual bolus, including bolus volumes or pressures.

The mechanisms responsible for the delay in intestinal gas transit elicited by dietary fibre are unknown. It is possible that the increased bulk of the high fibre diet provides a mechanical impediment to aboral gas movement. Consumption of a diet with 30 g of psyllium produces an increase in stool weight of 226 g/day. Prolongation of the lag phase conceivably could be secondary to an increased volume of stool within the colonic lumen which precludes evacuation of the initial bolus until a sufficient pressure is built up proximally by the jejunal perfused gas mixture.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard diet</th>
<th>High fibre diet</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolus flow rate (ml/min)</td>
<td>13.8 (0.6)</td>
<td>14.7 (0.6)</td>
<td>0.27</td>
</tr>
<tr>
<td>Bolus duration (s)</td>
<td>5.4 (0.4)</td>
<td>5.2 (0.4)</td>
<td>0.66</td>
</tr>
<tr>
<td>Bolus volume (ml)</td>
<td>68.2 (6.0)</td>
<td>70.7 (4.2)</td>
<td>0.66</td>
</tr>
<tr>
<td>Bolus pressure (mm Hg)</td>
<td>13.3 (1.8)</td>
<td>13.8 (1.9)</td>
<td>0.72</td>
</tr>
</tbody>
</table>

30 minute time period of gas perfusion on the standard diet versus the fibre supplemented diet ($p < 0.05$) (Fig 6C). Rates of gas flow during each bolus and bolus durations were greater on the high fibre diet compared with the standard diet ($p < 0.05$ by ANOVA). Results are mean (SEM), $n = 10$. 

Figure 6 Numbers of gas evacuations during the two hours of the study (A) and calculated per 30 minutes of recording time after excluding the lag period (B) are shown for the standard diet and the diet supplemented with psyllium. (A) Total numbers of gas evacuations were significantly less on the high fibre diet compared with the standard diet ($p < 0.05$). (B) After exclusion of the lag phase, numbers of bolus evacuations per 30 minutes remained reduced on the fibre supplemented diet compared with the standard diet ($p < 0.05$). (C) Finally, when comparing bolus evacuations during each 30 minute recording period, evacuation numbers were greater on the standard diet compared with the high fibre diet ($p < 0.05$ by ANOVA). Results are mean (SEM), $n = 10$. 

Table 1 Effects of fibre supplementation on properties of bolus gas evacuations

www.gutjnl.com
Altered in reflex responses of the colon to increased bulking by the fibre supplement also may modulate intestinal gas transit. Mucosal stimulation or muscle stretch by colonic bulking by the fibre supplement also may modulate intestinal alterations in reflex responses of the colon to increased.

Finally, it is possible that the retardation of gas flow by fibre supplementation might promote enhanced diffusion of the perfused gas into the bloodstream. This hypothesis cannot be tested using the current methodology. It is possible that utilisation of a washout method with an inert gas such as argon, as has been previously described, would provide quantification of volumes of gas retained within the gut on the two diets to answer this question. However, such a finding would not alter the main thrust of this investigation—that consumption of a high fibre diet modifies the dynamics of jejunal perfused gas mixtures. In conclusion, consumption of a diet supplemented with psyllium retards transit of gas perfused into the jejunum in healthy humans by prolonging the lag time to first evacuation and decreasing the numbers of bolus passages from the rectum after completion of the lag phase. These observations provide a possible explanation for the increase in gaseous symptoms, including bloating, observed on a high fibre diet.

ACKNOWLEDGEMENTS

This research was sponsored in part by a grant 1 K24 DK02726-01 from the National Institutes of Health.

Authors’ affiliations
S Gonlachanvit, R Coleski, C Owyang, W L Hasler, Division of Gastroenterology, Department of Internal Medicine, University of Michigan Medical Center, Ann Arbor, MI, USA

REFERENCES

A phenomenal response to treatment by an advanced tumour

Clinical presentation
A 44 year old woman presented with a longstanding history of epigastric pain, weight loss, and dysphagia. Upper gastrointestinal duodenoscopy demonstrated an 8 cm infiltrating tumour of the proximal (40 cm) stomach, and biopsy of the lesion demonstrated a necrotic solid tumour with a predominant epithelioid morphology arranged in small solid clusters with multiple scattered mitotic figures. Immunohistochemical staining revealed strong expression of vimentin, CD34, and c-kit in virtually all tumour cells. In view of her symptoms and histological findings, a contrast enhanced computed tomography (CT) scan of her abdomen was performed (fig 1).

Question
What do the investigations reveal as the likely diagnosis, and what are the treatment options for this patient?
See page 1616 for answer
This case is submitted by:
S H Rahman, A Ray, M Leahy, P J Guillou, G J Toogood
St James’s University Hospital, Leeds, UK

Correspondence to: Mr S H Rahman, St James’s University Hospital, Beckett St, Leeds LS2 2LY, UK; zak-rahman@lineone.net
doi: 10.1136/gut.2003.029611

Figure 1
Contrast enhanced computed tomography scan of the abdomen (left) and immunohistochemical staining of the biopsy specimen of the lesion (right).
Inhibitory actions of a high fibre diet on intestinal gas transit in healthy volunteers

S Gonlachanvit, R Coleski, C Owyang and WL Hasler

Gut 2004 53: 1577-1582
doi: 10.1136/gut.2004.041632

Updated information and services can be found at:
http://gut.bmj.com/content/53/11/1577

These include:

References
This article cites 35 articles, 11 of which you can access for free at:
http://gut.bmj.com/content/53/11/1577#BIBL

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/