

GASTROENTEROLOGY

Semiquantitative assessment of breath hydrogen testing

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Abstract

Background and Aim: A major use of breath hydrogen testing is to assess absorptive capacity for sugars to assist dietary design for management of gut symptoms. Qualitative reporting takes no account of the vigor of hydrogen response and provides little insight into degrees of malabsorption. This study aimed to describe a semiquantitative reporting method and to compare results with those reported qualitatively.

Methods: In consecutive Caucasian patients with Crohn's disease ($n = 87$), ulcerative colitis (59), functional gastrointestinal disorders (FGID) (162), and healthy controls (76), area under the curve was calculated for lactulose (15 g). This was compared with that for lactose (50 g) and fructose (35 g). Degree of malabsorption was categorized into arbitrary groups.

Results: Semiquantitative results for $\geq 30\%$ (designated "convincing") malabsorption was most similar to those using a qualitative cutoff value of 20 ppm, but in 38% and 21% of patients, the classification of malabsorption (nil or clinically significant) changed for fructose and lactose, respectively. Using a cutoff of 10 ppm, 49% and 5% were classified differently. Crohn's disease had a higher prevalence (42%) of convincing fructose malabsorption than controls (24%) or patients with FGID (33%) ($P < 0.02$). Highest prevalence of convincing lactose malabsorption (38%) was in ulcerative colitis, greater than controls (18%) and FGID (18%) ($P < 0.02$).

Conclusions: Semiquantitative assessment provides different results with different clinical implications in more than one third of patients, but disease-related alterations in prevalence are similar to those defined qualitatively. This method may be preferable because it lessens the confounding influence of the vigor of the hydrogen response.

Introduction

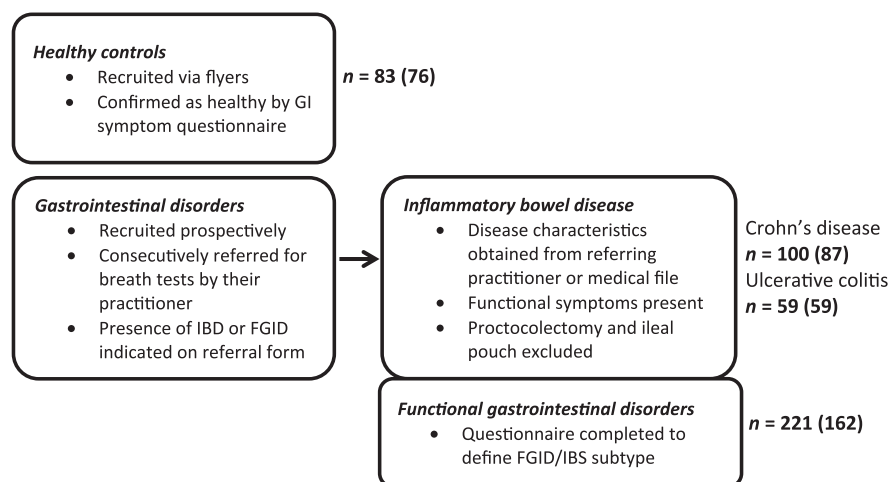
One of the major uses of breath hydrogen testing is to assess an individual's absorptive capacity for a test carbohydrate. The emerging field of a diet low in fermentable short-chain carbohydrates (also referred to as the low fermentable oligosaccharides, disaccharides, monosaccharides, and polyols [FODMAP] diet¹) in managing functional gastrointestinal symptoms benefits from breath testing to fine-tune the dietary approach. The term, FODMAP, describes fermentable oligosaccharides (fructans and galacto-oligosaccharides [GOS]), disaccharides (lactose), monosaccharides (fructose), and polyols (sorbitol and mannitol). When these carbohydrates are poorly absorbed in the small intestine of patients with functional bowel disorders such as irritable bowel syndrome (IBS), they can induce symptoms including abdominal pain, bloating, flatus, constipation, and/or diarrhea.² This occurs by virtue of their osmotic effect because of their small molecular size and by gas production from rapid fermentation by intestinal microbiota, leading to luminal distension.^{3,4}

There are significant interindividual differences in absorption of fructose and lactose in the small intestine varying from marked

malabsorption to complete absorption. This is by virtue of variance in the ability of the enterocyte protein, GLUT5, to transport fructose,^{5,6} and the activity of the brush border hydrolase, lactase, to digest lactose.⁷⁻⁹ Breath hydrogen testing is used to assess an individual's capacity to absorb fructose or to digest and subsequently absorb lactose in the small intestine. While the same might apply to polyols, such marked heterogeneity in absorptive capacity across individuals does not seem to be present.¹⁰ The oligosaccharides (fructans and GOS) are not breath tested as they are poorly absorbed in everyone because of the lack of human enzymes to hydrolyze them to individual hexoses.^{11,12}

Current methodology uses qualitative reporting of results; that is, strict criteria define if malabsorption is present or absent.¹³⁻¹⁵ However, there is good reason to find such expression of results unsatisfactory. There is currently controversy over how a positive result should be defined. Two definitions have been used most broadly; a rise in breath hydrogen of at least 10 ppm or 20 ppm above baseline. The lower cutoff has been said to include overproducers of hydrogen with frequent false positives,¹⁵⁻¹⁷ whereas the higher cutoff misses the proportion of people who produce only low levels of hydrogen following ingestion of a malabsorbed

Figure 1 Flow chart depicting recruitment of subjects. All subjects were recruited prospectively. Questionnaires were used to confirm the eligibility of healthy controls and those with functional gastrointestinal disorders (FGID). Referring practitioners or medical histories were examined to confirm the disease state and functional symptoms in those with inflammatory bowel disease. The number of breath testing records examined is given as “*n*.” The final number of breath testing records used in the study after exclusions summarized in Table 1 is given in brackets.



carbohydrate.^{18–20} There are pitfalls with both cutoff levels, and the fact that the amount of hydrogen appearing in the breath after malabsorption of a given amount of sugar known to be malabsorbed (lactulose) varies considerably (10–250 ppm²⁰), the use of a fixed cutoff level may be inappropriate. On receipt of results, dietitians and patients often question the degree of malabsorption, wanting further insight as to how much of the sugar was malabsorbed, and consequently the degree of dietary restriction necessary to improve their symptoms. The current qualitative assessment of breath testing outcomes does not enable this.

In 2009, qualitative data on fructose and lactose absorption using consistent breath hydrogen testing protocols across a range of gastrointestinal disorders and healthy controls were published.²¹ Using a cutoff of 10 ppm, it was demonstrated that fructose malabsorption is common in healthy volunteers (33%), with similar prevalence across gastrointestinal disorders including IBS. In Crohn's disease, however, the prevalence rose to 61% and was further increased with isolation of disease to the ileum (75%). This increase in prevalence was not explained by disease activity or the possibility of small intestinal bacterial overgrowth (SIBO) or rapid transit. Similar trends were seen across patient groups if a cutoff of 20 ppm was used to detect a positive result, although the prevalence rates were lower. In addition, concurrent malabsorption of fructose and lactose was most prevalent in Crohn's disease (29%). It was concluded that these findings may have pathogenic relevance, particularly for Crohn's disease.

Consideration should be given to the potential for quantitative analysis of breath hydrogen tests to provide more detailed information to patients and dietitians, and to give greater insight into differences across disease groups. The routine use of a known amount of a completely unabsorbed disaccharide, lactulose, in breath testing protocols potentially allows quantification of the amount of malabsorption of other sugars by the amount of hydrogen produced. This report aims to exploit this opportunity by examining the extent of malabsorption across the same patient groups used in the 2009 prevalence study and comparing quantitative results, which are less influenced by the vigor of hydrogen response, with qualitative results in order to determine differences in classification, to re-examine disease-specific differences and to introduce the concept of quantitative breath test analysis.

Materials and methods

Subjects. Breath hydrogen reports for lactulose, lactose, and/or fructose were collated from 83 healthy volunteers, 100 patients with Crohn's disease and 59 with ulcerative colitis (UC) who had functional symptoms without clinically significant disease activity, and 221 with functional gastrointestinal disorders (FGID). The selection and characterization of the patients have been described previously and is summarized in Figure 1.²¹

Breath hydrogen test protocol. The breath hydrogen testing protocol has been described previously.²¹ In brief, subjects consumed a diet low in fiber and fermentable carbohydrates the day prior to each breath test,²² fasting from 10 pm. The following morning, a fasting breath sample was taken using a Quintron Gastrolyzer or Microlyzer (Quintron Instrument Co., Milwaukee, WI, USA). The test solution was given and repeat breath samples were taken every 15 min for 3 h. Lactulose 15 g (15% weight/volume [w/v]), 35 g fructose (17% w/v), and 50 g lactose (25% w/v) were used as the test solutions. Lactulose was always tested first and then a variable order for lactose and fructose followed. Tests were performed with at most 1 week between them.

Semiquantitative analysis. In order to assess the degree of malabsorption of fructose and lactose, the area under the curve (AUC) of hydrogen production after each sugar was calculated. To do this, the values were corrected for baseline hydrogen content, and the AUC was then calculated using the trapezoidal rule. Because lactulose is almost completely malabsorbed, the lactulose AUC was considered to represent the hydrogen production associated with 15 g of malabsorbed carbohydrate. Assuming that each test sugar is equally fermented by an individual's microbiota and that the microbiota had not changed between testing days, the proportion of test sugar that was malabsorbed can be estimated by comparing this with the AUC for each test sugar using the following equation:

$$\text{Proportion of } \alpha \text{ malabsorbed (\%)} = ((\text{AUC}_\alpha / \text{AUC}_{\text{LL}}) * 15) / (\text{grams ingested test sugar}) * 100$$

Where α = test sugar (fructose or lactose); $AUC\alpha$ = area under the curve for test sugar, and AUC_{LL} = area under the curve for lactulose.

The results were expressed in grams of carbohydrate malabsorbed. Because the assumptions made in such calculations—that the functional activity of the microbiota does not change over time and that the amount of gas produced through fermentation is similar across different malabsorbed sugars—have not been tested, the degree of malabsorption was expressed semiquantitatively in three arbitrary categories: “no malabsorption” (< 10% of dose malabsorbed), “small degree of malabsorption” (10–29%), and “convincing malabsorption” ($\geq 30\%$). These categorical cutoff values were chosen in an attempt to exclude false-negatives because of low hydrogen production, while providing two separate positive categories that hypothetically may have useful clinical application in terms of determining how restrictive dietary change needs to be for symptom control. The validity of this categorization has yet to be investigated.

Statistical analysis. All statistical tests were performed using GRAPHPAD PRISM (version 3.00 for Windows, GraphPad Software, San Diego, CA, USA). All data were nonparametric with statistical tests used in line with this. Data for AUC were represented as median and interquartile range (IQR) with differences examined using Mann–Whitney test. The prevalence data across disease states were assessed using Kruskal–Wallis test, with Fisher’s exact test used to compare the proportion of patients demonstrating complete absorption and convincing malabsorption between groups. A Friedman test was used to assess differences in outcomes across all qualitative and semiquantitative reporting methodologies, with a Wilcoxon signed-rank test used to compare outcomes between methods. A *P* value of < 0.05 was considered significant.

Results

Subjects. Table 1 details the number of patients in each group, demographics, and exclusions. There were more male patients in the inflammatory bowel disease groups, but all groups were of similar age range. The final number of patients included from each disease group differed in the current study. In both studies, patients of Chinese/South-East Asian descent were excluded because of

their high risk of lactose malabsorption ($n = 10$). In the first study, those who failed to reach the set cutoff of hydrogen after lactulose (10 ppm) were excluded from analysis, but levels lower than this still allow for semiquantitative analysis as long as a clear curve (levels detected on at least three consecutive readings) was evident. As such, there were only 10 patients (2%) who produced inadequate hydrogen for semiquantitative analysis. In addition, the results in a proportion were technically not suitable for such analysis because of the use of two different breath collection devices (Quintron Gastrolyzer or Microlyzer) ($n = 66$, 14%). The final number of results from each patient group was therefore as follows; 76 healthy controls, 87 Crohn’s disease, 59 UC, and 162 FGID.

Area under the curve for lactulose. Comparison of the AUC for lactulose across all subject groups revealed no differences between groups (Fig. 2). The median (IQR) for AUC was as

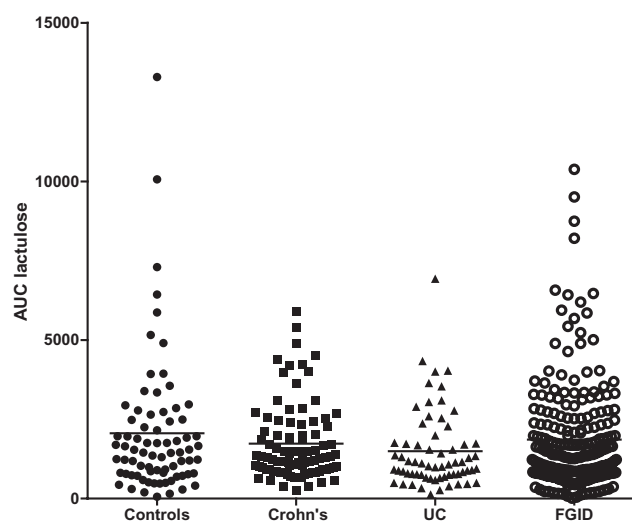


Figure 2 Comparison of the area under the curve (AUC) for lactulose across subject groups. There were no significant differences between groups for the area under the curve following lactulose (Mann–Whitney test).

Table 1 Comparison of demographics across the subject groups

Characteristic	Healthy controls	Functional gastrointestinal disorders	Crohn’s disease	Ulcerative colitis
<i>n</i>	83	221	100	59
Male (% total)	23 (28%)	41 (19%)	44 (44%) [†]	20 (34%) [‡]
Age, median (IQR) year	34 (29–46)	41 (29–55)	40 (31–50)	40 (30–52)
Chinese/South-East Asian Descent	7	3	0	0
Nonhydrogen producers	0	1	8	1
Different devices used	0	55	5	6
Final <i>n</i>	76	162	87	59

[†]More male subjects compared to functional gastrointestinal disorders ($P < 0.008$).

[‡]More men than for functional gastrointestinal disorders ($P = 0.01$).

IQR, interquartile range.

follows: 1451 (784–2488) for healthy subjects, 1320 (915–2265) for Crohn's disease, 1080 (750–1751) for UC, and 1328 (750–2486) for the FGID group.

Prevalence of fructose and lactose malabsorption using semiquantitative analysis. There were no differences observed across the groups (Kruskal–Wallis) on semiquantitative analysis of convincing fructose malabsorption (Table 2); however, Fisher's exact test between selected groups showed that patients with Crohn's disease had a higher prevalence of fructose malabsorption (42%) than healthy controls (24%) and FGID (33%) (Fisher's exact test; both $P < 0.02$). Likewise, for lactose malabsorption, significant differences were not observed across the groups, but analysis between individual disease states demonstrated that patients with UC had the highest prevalence (38%), significantly greater than healthy controls (18%) and FGID (18%) ($P < 0.02$). Although the 20 ppm qualitative data closely resembled the semiquantitative data, significant differences

between disease states are lost with the 20 ppm qualitative reporting.

Patients with FGID were further examined in the different subgroups using semiquantitative analysis (constipation-predominant IBS, diarrhea-predominant IBS, IBS with mixed bowel habits, functional constipation, functional diarrhea, functional bloating, functional gut disorder unsubtyped). There were no significant differences for the prevalence of fructose or lactose malabsorption, although this may be due to small sample size. Results are tabulated in Table 3, with highest prevalence of convincing fructose malabsorption in the constipation-predominant IBS (45%) and functional diarrhea groups (50%) and highest prevalence of convincing lactose malabsorption in the functional constipation and functional bloating groups (both 20%). If the patients with FGID were grouped according to predominant bowel habit—diarrhea-predominant ($n = 60$) or constipation-predominant ($n = 50$)—no differences were evident: 35% of each group demonstrating convincing fructose malabsorption, and 15% and 21% demonstrating convincing lactose malabsorption, respectively.

Table 2 Prevalence of malabsorption based on semiquantitative analysis versus standard analysis. There were no significant differences across the disease groups by Kruskal–Wallis tests (all $P > 0.03$)

		Controls	Crohn's disease	Ulcerative colitis	FGID
Number		76	87	59	162
Fructose	Qualitative 10 ppm cutoff	34%	61% [†]	42%	45%
	Qualitative 20 ppm cutoff	24%	33%	24%	28%
	Semiquantitative:				
	Any $\geq 10\%$	56%	70%	67%	51%
	Small 10–29%	32%	28%	31%	18%
Lactose	Convincing $\geq 30\%$	24%	42% [‡]	36%	33%
	Qualitative 10 ppm cutoff	18%	42%	40% [§]	25%
	Qualitative 20 ppm cutoff	12%	19%	29%	19%
	Semiquantitative:				
	Any $\geq 10\%$	29%	48%	49%	27%
	Small 10–29%	11%	29%	11%	9%
	Convincing $\geq 30\%$	18%	19%	38% [¶]	18%

[†]Crohn's disease has a higher prevalence of fructose malabsorption at 10 ppm compared with other subject groups (Fisher's exact test, $P < 0.03$).

[‡]Crohn's disease has a higher prevalence of semiquantitative convincing fructose malabsorption compared with healthy controls and FGID ($P < 0.02$).

[§]Ulcerative colitis has a higher prevalence of fructose malabsorption at 10 ppm compared with other subjects group ($P < 0.05$).

[¶]Ulcerative colitis has a higher prevalence of semiquantitative convincing lactose malabsorption compared with healthy controls and FGID ($P < 0.02$). FGID, functional gastrointestinal disorders.

Table 3 Prevalence of malabsorption based on semiquantitative analysis for FGID subtypes

	FD	IBS-D	FC	IBS-C	FGD-U	IBS-M	FB
Number	24	36	30	20	18	16	18
Fructose							
	Semiquantitative degree of malabsorption:						
	Any $\geq 10\%$	58%	53%	42%	70%	28%	38%
	Small 10–29%	8%	28%	14%	25%	6%	13%
Lactose	Convincing $\geq 30\%$	50%	25%	28%	45%	22%	25%
	Semiquantitative degree of malabsorption:						
	Any $\geq 10\%$	19%	25%	40%	22%	20%	22%
	Small 10–29%	5%	9%	20%	0%	7%	22%
	Convincing $\geq 30\%$	14%	16%	20%	22%	13%	0%

FB, functional bloating; FC, functional constipation; FD, functional diarrhea; FGD-U, functional gut disorder-unsubtyped; FGID, functional gastrointestinal disorders; IBS-C, constipation predominant irritable bowel syndrome; IBS-D, diarrhea predominant IBS; IBS-M, mixed type IBS.

Comparison of prevalence data across qualitative and semiquantitative analysis. Table 2 shows the prevalence of malabsorption of fructose and lactose in each subject group semiquantitatively as well as qualitatively using a cutoff of 10 ppm and 20 ppm as per previous work.²¹ The semiquantitative data set shows that, at a cutoff of 10% malabsorption, the prevalence rates are extremely high, higher than the low 10 ppm qualitative cutoff. With convincing malabsorption of $\geq 30\%$ likely to be more clinically relevant, the results then become more comparable to the qualitative reporting. The 10 ppm cutoff leads to greater prevalence outcomes. The qualitative cutoff of 20 ppm more closely representing the semiquantitative convincing malabsorption data, with the exception of inflammatory bowel disease.

Change in classification of results using semiquantitative versus qualitative analysis. Figure 3 outlines the change in classification of the qualitative results when semiquantitative methods were applied. The semiquantitative classification of convincing malabsorption was evident in 61% and 76% of those labeled with fructose malabsorption using the 10 and

20 ppm cutoffs, respectively. Similarly, semiquantitatively convincing lactose malabsorption was evident in 60% and 76% of those using the 10 and 20 ppm cutoff, respectively. Collectively for all fructose and lactose results, Friedman comparison across the three methodologies (10 ppm, 20 ppm, and semiquantitative) demonstrated significant differences ($P < 0.0001$). Wilcoxon signed-rank test demonstrated 10 ppm yields significantly different results ($P < 0.0001$) compared with both 20 ppm and the semiquantitative methodology. There was no significant difference, however, between the 20 ppm cutoff and convincing malabsorption results ($P = 0.27$).

Discussion

This new analytical method for the semiquantitative interpretation of breath tests enables researchers, practitioners, and patients to gain a broader understanding of breath test outcomes. The traditional qualitative reporting yields positive or negative interpretation only. In the clinical application of these breath tests, patients seek more insight. Their questions might include, for example,

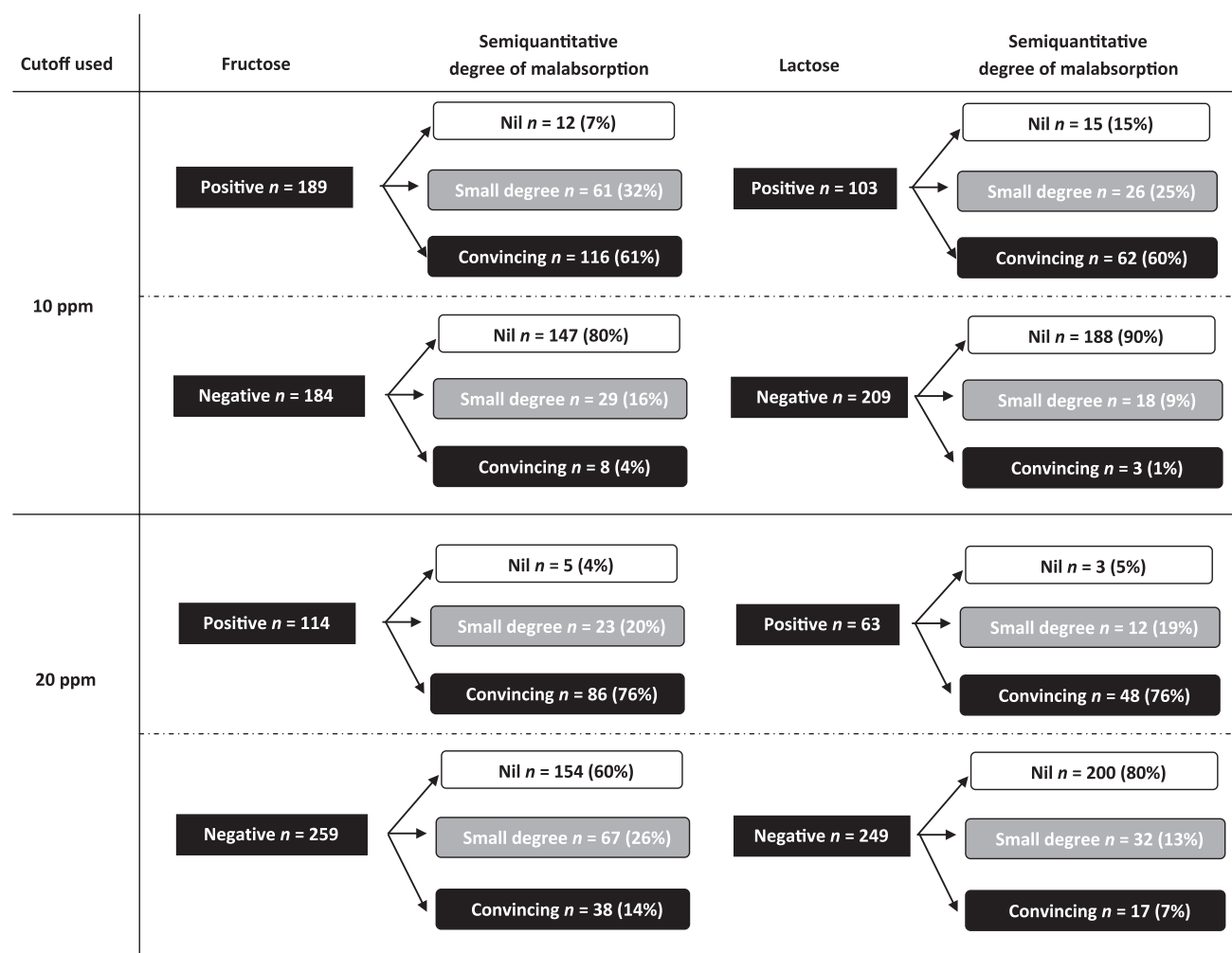


Figure 3 Change in classification of qualitative results using semiquantitative analysis.

whether a small (50 g) slice of watermelon might be tolerated even though fructose malabsorption is present, or whether a small amount (30 mL) of milk in tea can be consumed even though malabsorption of lactose was reported. Small allowances like these improve compliance and acceptability of dietary restrictions. Certainly, further work is needed to confirm and define the translation of semiquantitative reporting into the degree of dietary restriction required, but physiologically, the methodology is meaningful and can be trialed in patient care.

The breath hydrogen response to lactulose is a key to any quantification of carbohydrate malabsorption. In order for this to be a reliable marker, three elements are assumed. First, breath hydrogen production needs to be adequate on lactulose testing to provide an AUC for comparison. Approximately 10% of the population will produce inadequate hydrogen to lactulose,²⁰ although with semiquantitative analysis the degree of hydrogen needed is lower than that required with qualitative cutoff values, with 98% of the breath test reports assessed for inclusion in the current study producing adequate hydrogen. Still, there is a proportion of the population in which semiquantitative (and qualitative) analysis is void. Possibly, breath methane might be used in such situations, but this was not evaluated in the present study. The variability that we observe with methane levels and the fact that one in two nonhydrogen producers will also produce inadequate levels of methane, suggests that semiquantitative analysis on methane would not be reliable.²⁰ Secondly, reproducibility of repeated AUC for lactulose (or indeed fructose or lactose) has not been investigated and its acceptability is, therefore, unknown. However, the time of first rise of breath hydrogen after lactulose appears to have reasonable intra-individual reproducibility.^{23,24} Thirdly, it is assumed that the same level of gas is produced when different sugars of the same dose are malabsorbed, but this has not been formally evaluated. Because of these limitations and uncertainties, the accuracy of the absolute amount of malabsorbed sugar may be limited, but semiquantitative classifications are likely to be valid.

The prevalence of fructose and lactose malabsorption ($\geq 10\%$) based on semiquantitative analysis was higher across all cohorts than that achieved through qualitative analysis based on a cutoff of 10 ppm hydrogen for at least two consecutive readings. These may be true findings, but the clinical relevance of each of these results needs consideration. For example, malabsorption of 10% of the fructose found in common fruits and vegetables is likely to lead to relatively minor physiological effects in the intestine and be of minimal clinical significance. More importantly, 10% of fructose in excess of glucose may only be malabsorbed when the ingested dose is high (e.g. 35 g). With lower doses, fructose absorption is more efficient and malabsorption is likely not to occur in this situation. Categories of “small degree” and “convincing” malabsorption were created in an attempt to examine a degree of malabsorption more likely to be important clinically. Prevalence rates for convincing malabsorption were at least 25% less commonly observed than those when malabsorption was determined qualitatively.

Qualitative reporting of breath tests relies on the vigor of hydrogen response by the individual. It is clear from all breath test studies that the same dose of lactulose, fructose, or lactose gives a varied interindividual response. Reliance on strict cutoff levels is, therefore, problematic; some individuals may have heightened hydrogen response, detected as a positive regardless of the cutoff

value, but may be deemed not clinically relevant when compared semiquantitatively. The same uncertainties come with those that have a diminished hydrogen response, negative on qualitative reporting, but their low lactulose response may declare convincing malabsorption of fructose and/or lactose that would benefit from dietary modification and would otherwise have been left untreated. There has been ongoing controversy over what the cutoff should be, as exemplified by the varied interpretations of the current data. Theoretically, the semiquantitative methodology can minimize the effects of low or high hydrogen production and stop the controversy over which cutoff should be used. Furthermore, if the actual amount of malabsorbed sugar is calculated by utilizing the AUC and lactulose results, the clinically relevant interpretation (i.e. whether dietary restriction of that sugar is warranted or not to reduce clinical symptoms) changed in more than one in three patients. Whether indeed relief of symptoms guided by semiquantitative interpretation of the breath hydrogen testing is better or worse than being guided by the use of strict cutoff values would require further study.

As previously reported,²¹ fructose and lactose malabsorption is not infrequently observed in healthy controls. One in three had any and one in four convincing evidence of fructose malabsorption, while nearly one in five had convincing evidence of lactose malabsorption. Such findings may create concern among practitioners and researchers that breath testing is not useful as fructose malabsorption is common in people without symptoms. However, in the setting of a gastrointestinal disorder characterized, for example, by visceral hypersensitivity, such malabsorption becomes problematic because rapidly fermented carbohydrates that increase gas and fluid content of the bowel is associated with bloating, distension, excessive flatus, and motility disturbances, and subsequent reduction of their intake is associated with symptomatic improvement.^{2,4}

Semiquantitative assessment of fructose and lactose absorption has confirmed similar patterns of malabsorption in patients with FGID as healthy controls. While convincing malabsorption was numerically higher at 33% than that for healthy controls (24%), this difference did not reach statistical significance. Furthermore, the hydrogen response to lactulose was similar in the two groups. These data add further support to the concept that the ability to absorb fructose or the fermentative activities of the microbiota in patients with FGID are not abnormal overall and that the response to such luminal distension is where the difference lies. Breakdown into FGID subtypes according to the Rome III criteria showed no consistent differences in fructose absorption patterns. Interestingly, patients with functional diarrhea and constipation-predominant IBS both revealed the highest prevalence of fructose malabsorption, but confusingly, the similar subtypes of functional constipation and diarrhea-predominant IBS had low prevalence. This is most likely a function of the small numbers of patients in the subgroups.

Disease-related abnormalities were again observed in patients with Crohn's disease and UC, the new way of analyzing the data overall not changing the trends. Thus, Crohn's disease has the highest prevalence of convincing fructose malabsorption (42%), although the significantly higher prevalence of lactose malabsorption in Crohn's disease seen in qualitative analysis was lost. This clearly reflects the fact that minor degrees of lactose malabsorption were common in that patient group. In contrast, patients with UC maintained a high level of lactose malabsorption with this analysis.

The high prevalence of fructose and/or lactose malabsorption in patients with IBD provides additional data to implicate a role for sugar malabsorption in these conditions. This did not appear to be associated with inflammation nor the presence of SIBO or rapid transit, according to the lactulose response.²¹ Whether these sugars are malabsorbed in genetically susceptible people prior to the onset of IBD with dietary intake of these sugars relevant to the pathophysiology of the disease is an interesting hypothesis⁸ that needs further work. Application of a newly developed and validated dietary assessment tool that can analyze intake of these fermentable sugars²⁵ may better define the link between IBD and prediagnosis dietary FODMAP intake.

In summary, this new semi-quantitative analytical method enables researcher, practitioner, and patient to gain further insight into the degree of malabsorption of fructose and lactose. The current qualitative methodology with cutoffs of 10 or 20 ppm has its limitations, relying on strong hydrogen production and potentially overestimating the prevalence of malabsorption. Semi-quantitative ranking of the results according to the degree of malabsorption and focusing on those depicting convincing malabsorption provides different guidance in a considerable proportion of patients and should improve the clinical relevance of the test. Further work is required to evaluate the clinical utility of this way of expressing data, particularly in defining the correlation between the degree of sugar malabsorbed and the level of dietary restriction required to improve symptoms.

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