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Influence of orocaecal transit time on hydrogen excretion after carbohydrate malabsorption

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SUMMARY **The aim of the present study was to determine whether changes in orocaecal transit time (OCTT) affect the magnitude of the breath hydrogen (H_2) excretion after ingestion of unabsorbable carbohydrate. We studied eight healthy subjects by interval sampling of end expiratory H_2 concentration for 12 hours after ingestion of: (1) 10 g lactulose (L); (2) 10 g L with 20 mg metoclopramide (M) as tablets; (3) 20 g L, and (4) 20 g L with 7·5 mg diphenoxylate (D) as tablets, in random order. In spite of significant changes in OCTT after M and D, there were no significant changes, compared for the same dose of lactulose, with respect to area under the breath H_2 excretion curves, peak increments of H_2 concentration or timing of the peak increment. We conclude that, within the ranges observed, the OCTT does not significantly affect the shape of the H_2 concentration *versus* time curves. In comparative studies estimates of the degree of carbohydrate malabsorption on the basis of breath H_2 concentration may be valid in spite of differences in OCTT.**

Breath hydrogen (H_2) tests in the form of interval sampling of end expiratory H_2 concentrations are widely used in studies of carbohydrate absorption. Quantitative estimates of the amount of carbohydrate malabsorbed from a given test meal is generally obtained by comparing the areas under the breath H_2 excretion curves after different meals or by comparing with the area obtained after a given dose of the non-absorbable disaccharide lactulose.[1-6] This procedure implies that extrapolation of data from the more simple interval sampling of H_2 concentrations[7] to quantitative measurements of total H_2 excretion[8] is valid. It has been suggested that quantitative estimates of carbohydrate malabsorption are valid on the basis of breath H_2 concentration only if it is assumed that the colonic entry rate of the test carbohydrate and lactulose is equivalent.[9] This suggestion could challenge the validity of quantitative estimates of carbohydrate malabsorption when significant differences of the orocaecal transit times between different test meals exist. The relationship between upper intestinal transit *per se*, however, and colonic H_2 production is not known. We have therefore investigated the effect of pharmacologically induced changes in orocaecal transit time on the H_2 excretion as measured by interval sampling of end expiratory breath H_2 concentrations after different loads of lactulose.

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Methods

SUBJECTS

Eight healthy adults (seven men and one woman, aged 21–33 years) were studied. The subjects were taking no other medication including antibiotics, salicylates and laxatives, they had no history of recurrent or present chronic gastrointestinal or pulmonary disease. No subjects had lactose intolerance. All subjects were H_2 producers ($\geq$10 ppm sustained rise of H_2 concentration after 10 g lactulose with 100 ml tap water). Blood screening tests were normal.

BREATH TESTS

Breath H_2 excretion was measured by interval sampling of end expiratory H_2 concentrations on a GMI (Gas Measurements Instruments Ltd, Renfrew, Scotland) H_2 monitor.[10] After at least 12 hours overnight fast, the subjects had a mouth rinse with a 0·1% chlorhexidine solution for two minutes,

thereafter repeated, and ended with a tap water swill.[11 12] In all breath tests end expiratory H_2 concentrations were collected in duplicate from the mouth in 20 ml plastic syringes (Once^R) fitted with a Y-piece. Samples were taken before lactulose ingestion and every 15 minutes for seven hours and immediately analysed. The study was extended to 12 hours, and during the last five hours samples were taken every 30 minutes in Becton-Dickinson^R 20 ml plastic syringes, which were stored overnight at 5°C for analysis the next morning.[13] Smoking and sleeping was not allowed and the subjects were non-ambulant. During the study period and for the 24 hours after each test the subjects completed a standardised symptom score.[4]

DESIGN OF THE STUDY

All breath tests were carried out within a period of two months and were coordinated with a separate study of quantifying carbohydrate malabsorption (Rumessen *et al*, in preparation). A minimum of six days elapsed between the difference tests to avoid colonic bacterial metabolic changes.[14 15] All subjects initially received 10 g (15 ml) lactulose (SAD) in 100 ml water. The lactulose solution contained 667 mg lactulose, 60 mg lactose, and 110 mg galactose per ml (according to the supplier). Subsequently the following tests were performed in random order: (1) 10 g lactulose in 100 ml water; (2) 10 g lactulose in 100 ml water and 20 mg metoclopramide (Primperan^R) as tablets 45 minutes before the test solution. Each tablet of 10 mg contained 34 mg lactose (according to the supplier); (3) 20 g lactulose in 200 ml water; (4) 20 g lactulose in 200 ml water and 7·5 g diphenoxylate (Retardin^R) as tablets, 45 minutes before the test solution. Each tablet of 2·5 mg contained 25 microgram atropine and 145 mg lactose (according to the supplier); (5) Fasting except for tap water without restrictions. During the course of all tests (incl no 5) a standardised meal consisting of 100 g minced meat stew together with 50 g boiled rice and 150 ml tap water was given within four hours, but never before the orocaecal transit time was determined. The meal was consumed within a period of 15 minutes.

This meal caused no significant H_2 production neither at ingestion nor during the rest of the study period (Rumessen *et al*, in preparation).

Table *Hydrogen excretion after changes of orocaecal transit time (OCTT) of different lactulose (L) loads with 20 mg metoclopramide (M) or 7·5 mg diphenoxylate (D) in eight subjects*

	OCTT (min)	*AUC§ (ppm×min×10^{-2})*	*Peak-H_2§ (ppm)*	*t-peak§ (min)*
10 g L	90*	125	60	75
	(68–150)‡	(91–164)	(41–68)	(45–90)
10 g L+M	45*	106	44	128
	(30–56)	(56–178)	(30–66)	(38–214)
20 g L	60†‡	243	78	150
	(15–75)	(182–334)	(56–126)	(90–206)
20 g L+D	75†	187	73	143
	(45–105)	(137–345)	(60–93)	(75–214)

*The OCTT was significantly shorter after M ($p<0·01$); †The OCTT was significantly longer after D ($p<0·05$); ‡The OCTT of 10 g L was significantly longer compared with 20 g L ($p<0·05$); §For the same lactulose loads there were no significant differences ($p>0·10$)
AUC: Area under the H_2 excretion curve from OCTT to 12 hours minus area under lowest previous value in the same period.
Peak-H_2: Maximal rise of H_2 concentration during study period.
t-peak: Time from OCTT to peak-H_2.
Results are given as medians (interquartile ranges).

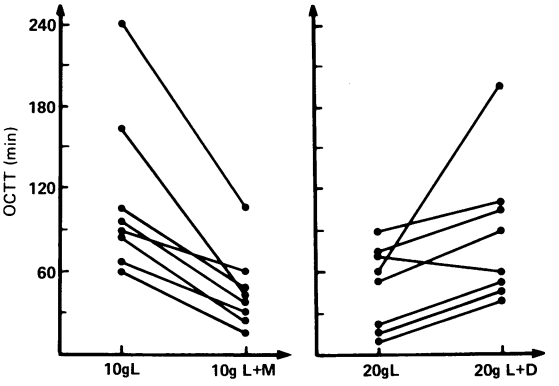

Figure *Effect of 20 mg metoclopramide (M) and 7·5 mg diphenoxylate (D) as tablets on the orocaecal transit times (OCTT) of different doses of lactulose (L) ($p<0·01$ (M), $p<0·05$ (D)).*

CALCULATIONS AND STATISTICS

The following variables were determined and compared for the same dose of lactulose: (1) Orocaecal transit time (OCTT), as the interval between ingestion and the initial sustained rise in breath H_2 concentration of 10 ppm or more;[16] (2) Maximal rise of H_2 concentration from lowest previous values (peak-H_2); (3) Time in minutes from OCTT to peak H_2 (t-peak); (4) Area under the H_2 concentration *versus* time curves from the OCTT according to the trapezoidal rule (AUC). AUC's were calculated as: (a) Area under the curve minus area under the lowest previous values; (b) Area under the curve minus area under each individual fasting curve.

These areas were calculated for the first two and four hours of the sustained increase in H_2 concentration as well as for the whole period from OCTT to 12 hours. Baseline H_2 concentrations were not reached in two subjects after 20 g lactulose and in two others after 20 g lactulose+diphenoxylate. The small additional areas were calculated by extrapolation to base line.

We furthermore compared the OCTT of 10 g lactulose with that of 20 g lactulose. The reproducibility of the initial 10 g lactulose load and the 10 g load used for calculation and comparison is reported elsewhere (Rumessen *et al*, in preparation).

STATISTICAL ANALYSIS

We used non-parametric statistics (Pratt's test, Spearmans rank correlation analysis), and the results were consequently expressed as medians and interquartile ranges. $p<0.05$ was considered significant.

ETHICS

The study was carried out in accordance with the Helsinki Declaration II, and the study protocol was approved by the Copenhagen County medical ethics committee.

Results

Our results are summarised in the Table.

A significant shortening of OCTT was observed after metoclopramide ($p<0.01$) and OCTT's were significantly increased after diphenoxylate ($0.01<p<0.05$) (Figure, Table). The difference in OCTT between 10 g lactulose and 20 g lactulose was significant ($0.01<p<0.05$) (Table). Irrespective of method of calculation, for the same dose of lactulose the changes in AUC's or peak-H_2 when metoclopramide or diphenoxylate was given were not significant ($p>0.10$). There was, however, a tendency towards lower H_2 excretion after diphenoxylate (Table). Similarly, there were no significant changes in timing of the peak-H_2 value when metoclopramide or diphenoxylate was given ($p>0.10$) (Table). Irrespective of whether metoclopramide or diphenoxylate was taken, there was no overall correlation between OCTT and H_2 production for each dose of lactulose ($p>0.50$). The AUC's and H_2-peaks of the initial 10 g lactulose load and the 10 g lactulose load used for randomised comparison were not significantly different ($p>0.10$), and indicated no change of the overall H_2-excretion pattern during the study. Apart from one subject complaining of moderate borborygmia after 20 g lactulose, the gastrointestinal symptoms were scored as none or mild in all studies with no differences between the test meals. No adverse drug reactions were noted.

Discussion

The present findings indicate that significant changes of the OCTT do not significantly influence the H_2 excretion as measured by interval sampling of end expiratory H_2 concentrations after different lactulose loads. There were no indications of changes in the overall H_2 excretion pattern during the study period, and the results are not likely to be explained by colonic adaptation or other period effects. There is no evidence suggesting an effect of metoclopramide or diphenoxylate/atropine on colonic bacterial metabolism and metoclopramide seems to have little effect on motility of the large intestine.[17] The lactose content of the tablets was negligible and irrelevant. Although the material is small and the data show rather large variation, it seems justified to conclude that the OCTT *per se*, within the ranges observed, does not significantly influence the overall pattern of H_2 excretion. Quantitative estimates of carbohydrate malabsorption, whether expressed as AUC's or peak increments of H_2 production, may therefore be widely independent of the OCTT's of the substances compared. There was, however, a tendency towards lower H_2 excretion after diphenoxylate, but no tendencies were apparent after metoclopramide, although this substance had the greatest effect on OCTT. We cannot, however, exclude the possibility that more extreme differences in transit times may unmask an influence on H_2 excretion in a larger sample size, and it is not possible to control all conceivable confounding factors in a study like this.

It is essential for the validity of breath H_2 tests that the H_2 response to a given load of malabsorbed carbohydrate is rather insensitive to changes of the OCTT within physiological ranges. This is so because: (1) One of the main determinants of OCTT is indeed the malabsorbed amount of carbohydrate itself.[18] This is illustrated in the present study by the significantly shorter transit times of 20 g lactulose loads compared with 10 g doses. This confirms earlier findings,[16 18] and was indeed the reason why we used different doses of lactulose for metoclopramide and diphenoxylate to exert their effects upon. If, therefore, breath H_2 tests were very sensitive to changes in transit time, quantitative estimates of malabsorbed carbohydrate would be inherently uninterpretable; (2) If a non-absorbable sugar such as lactulose is used for comparison, the interpretation of the H_2 evolution following more complex meals or sugars (as – for example, starch) would be invalid because of the generally more prolonged orocaecal transit times of the latter.[18]

The influence of the OCTT *per se* on the H_2 excretion subsequent to carbohydrate malabsorption has, however, not been studied earlier.

It has been observed that delayed gastric emptying of lactulose due to addition of glucose does not affect the AUC's of the corresponding H_2 excretion curves.[19] The effect of both metoclopramide and diphenoxylate on OCTT as observed by us is probably mainly on small intestinal transit.[20 21] Our results are not necessarily in conflict with the findings of

Read *et al*[9] that different colonic entry rates of carbohydrate may affect the timing and the magnitude of the peak H_2 production. It was shown[9] that fast colonic infusion of lactulose produced a greater H_2 response than slow infusion of the same dose. However, the difference in infusion rates used (7·5 times) was rather great, and AUC's were not compared. Furthermore, the OCTT's and the colonic entry rates of malabsorbed carbohydrate are not necessarily correlated,[22] and it is conceivable that substances with greatly different ileal emptying rates may provoke different H_2 responses. In a recent study,[23] however, a good correspondence was found between the H_2 production produced by ingestion of lactulose and infusion of starch.

Breath H_2 tests have been used to investigate the effect of drugs on upper intestinal transit.[24,25] The present study confirms earlier observations supporting the validity of using breath H_2 tests for this purpose.[26] Our findings may furthermore support the use of breath H_2 tests for evaluation of drugs influencing *both* intestinal absorption *and* upper intestinal transit time.

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References

1 Anderson IH, Levine AS, Levitt MD. Incomplete absorption of the carbohydrate in all-purpose wheat flour. *N Engl J Med* 1981; **304:** 891–2.

2 Kolars JC, Levitt MD, Aouji M, Saviano DA. Yogurt – and autodigesting source of lactose. *N Engl J Med* 1984; **310:** 1–3.

3 Thornton JR, Dryden A, Kelleher J, Losowsky MS. Does super efficient starch absorption promote diverticular disease? *Br Med J* 1986; **292:** 1708–10.

4 Rumessen JJ, Gudmand-Høyer E. Absorption capacity of fructose in healthy adults. Comparison with sucrose and its constituent monosaccharides. *Gut* 1986; **27:** 1161–8.

5 Levitt MD, Hirsh P, Fetzer CA, Sheahan M, Levine AS. H_2 excretion after ingestion of complex carbohydrates. *Gastroenterology* 1987; **92:** 383–9.

6 Harms H-K, Bertele-Harms R-M, Bruer-Kleis TA. Enzyme substitution therapy with the yeast Saccharomyces cerevisiae in congenital sucrase-isomaltase deficiency. *N Engl J Med* 1987; **316:** 1306–9.

7 Metz G, Jenkins DJA, Peters TJ, Newman A, Blendis LM. Breath hydrogen as a diagnostic method for hypolactasia. *Lancet* 1975; i: 1155–7.

8 Bond JH, Levitt MD. Use of pulmonary hydrogen (H_2) measurements to quantitate carbohydrate absorption. Study of partially gastrectomized patients. *J Clin Invest* 1972; **51:** 1219–25.

9 Read NW, AL-Janabi MN, Bates TE, *et al*. Interpretation of the breath hydrogen profile obtained after ingesting a solid meal containing unabsorbable carbohydrate. *Gut* 1985; **26:** 834–42.

10 Rumessen JJ, Kokholm G, Gudmand-Høyer E. Methodological aspects of breath hydrogen (H_2) analysis. Evaluation of a H_2 monitor and interpretation of the breath H_2 test. *Scand J Clin Lab Invest* 1987; **47:** 555–60.

11 Thompson DG, O'Brien JD, Hardie JM. Influence of the oropharyngeal microflora on the measurement of exhaled breath hydrogen. *Gastroenterology* 1986; **91:** 853–60.

12 Mastropaolo G, Rees WDW. Evaluation of the hydrogen breath test in man: definition and elimination of the early hydrogen peak. *Gut* 1987; **28:** 721–5.

13 Rumessen JJ, Gudmand-Høyer E. Retention and variability of hydrogen (H_2) samples stored in plastic syringes. *Scand J Clin Lab Invest* 1987; **47:** 627–30.

14 Perman JA, Modler S, Olson AS. Role of pH in production of hydrogen from carbohydrates by colonic bacterial flora. Studies in vivo and in vitro. *J Clin Invest* 1981; **67:** 643–50.

15 Florent C, Flourie B, Leblond A, Rautureau M, Bernier J-J, Rambaud J-C. Influence of chronic lactulose ingestion on the colonic metabolism of lactulose in man (an *in vivo* study). *J Clin Invest* 1985; **75:** 608–13.

16 Bond JH, Levitt MD. Investigation of small bowel transit time in man utilizing pulmonary hydrogen (H_2) measurements. *J Lab Clin Med* 1975; **85:** 546-55.

17 Schultze-Delrieu K. Metoclopramide. *Gastroenterology* 1979; **77:** 768–79.

18 Read NW, Miles CA, Fisher D, *et al*. Transit of a meal through the stomach, small intestine, and colon in normal subjects and its role in the pathogenesis of diarrhea. *Gastroenterology* 1980; **79:** 1276–82.

19 Rosado JL, Deodhar AD, Bourges H, Solomons NW. The effect of the digestion products of lactose (glucose and galactose) on its intraintestinal, in vivo hydrolysis by exogeneous microbial Beta-D-Galactosidase. *J Am Coll Nutr* 1986; **5:** 281–90.

20 Holgate AM, Read NW. Metoclopramide reduces carbohydrate absorption in man. *Br J Clin Pharmacol* 1985; **19:** 67–72.

21 Nilsson F, Johansson H. A double isotope technique for the evaluation of drug action on gastric evacuation and small bowel propulsion studied in the rat. *Gut* 1973; **14:** 475–7.

22 Phillips SF, Quigley EMM, Kumar D, Kamath PS. Motility of the ileocolonic junction. *Gut* 1988; **29:** 390–406.

23 Flourié B, Florent C, Etanchaud F, Edvard D, Franchisseur C, Rambaud J-C. Starch absorption by healthy man evaluated by lactulose hydrogen breath test. *Am J Clin Nutr* 1988; **47:** 61–6.

24 Basilisco G, Bozzani A, Camboni G, *et al*. Effect of loperamide and naloxone on mouth-to-caecum transit time evaluated by lactulose hydrogen breath test. *Gut* 1985; **26:** 700–3.

25 O'Brien JD, Thompson DG, McIntyre A, Burnham WR, Walker E. Effect of codeine and loperamide on upper intestinal transit and absorption in normal subjects and patients with postvagotomy diarrhoea. *Gut* 1988; **29:** 312–8.

26 Van Wyk M, Sommers K, Steyn GW. Evaluation of gastrointestinal motility using the hydrogen breath test. *Br J Clin Pharmacol* 1985; **20:** 479–81.