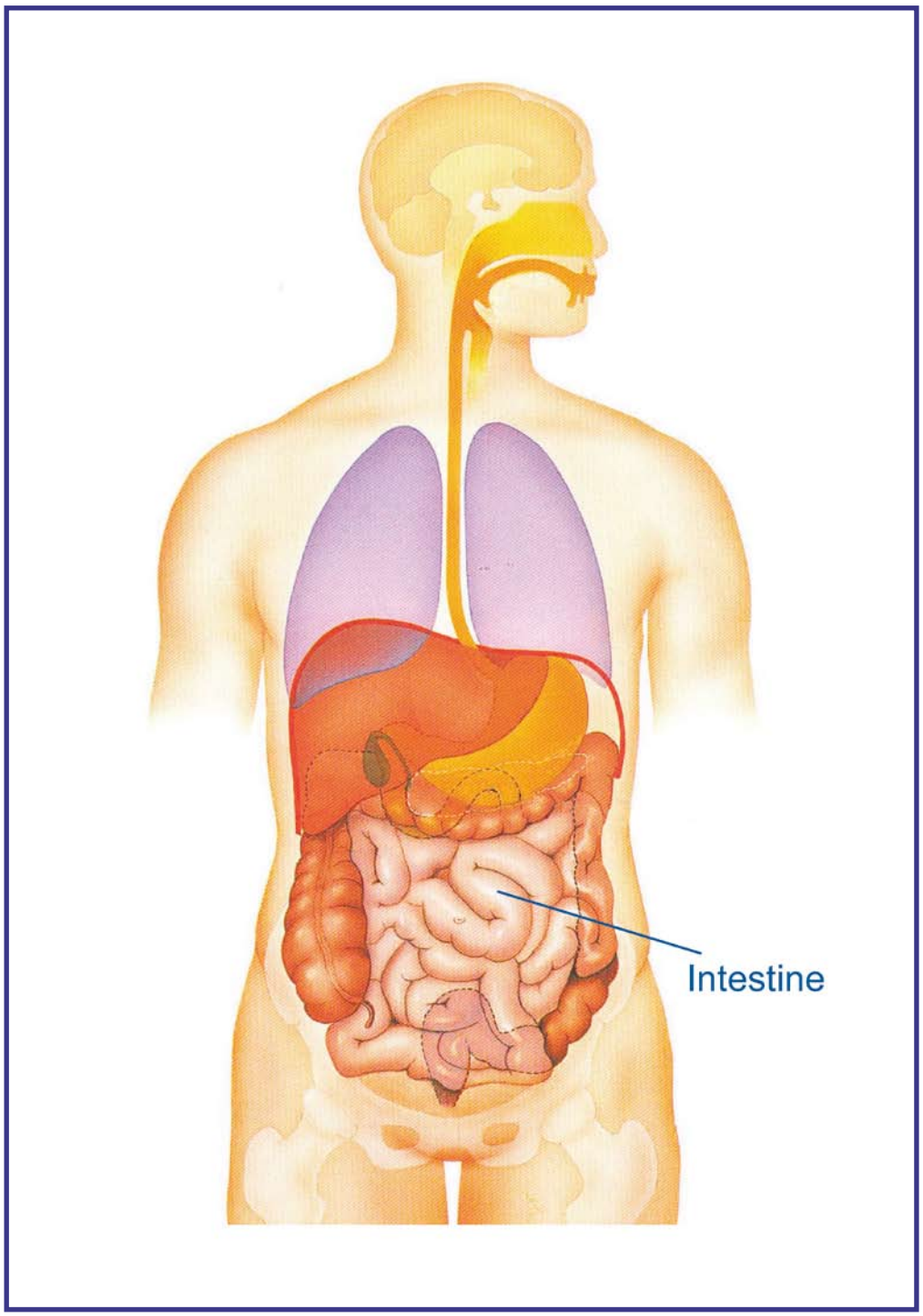
Protocols - ^{13}C Breath Tests - INTESTINE



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Introduction

^{13}C Breath Test protocols

This folder contains a set of protocols describing the principles and general test procedures for today's most relevant ^{13}C Breath Tests to study specific functions of the liver, pancreas, stomach and intestine. The list will be updated regularly adding additional tests or additional information on the already described tests.
The information is meant as a start to enter the field of stable isotope ^{13}C Breath testing initiated by the interest in a specific test. To actually be able to introduce a test in your hospital you must familiarize yourself with basic knowledge of breath testing with ^{13}C substrates and the existing knowledge on the particular application of interest. There is no such thing as a standard protocol for all tests.

^{13}C Breath Testing: principle and requirements

A ^{13}C Breath Test consists of the administration to a patient of a ^{13}C labeled substrate that is metabolized by a specific enzyme system resulting in $^{13}CO_2$ as the end product. To monitor the enzyme response ^{13}C enrichment is measured in breath CO_2.
The total procedure of ^{13}C Breath testing includes the definition of the preparation of the patient before the test, administration of the ^{13}C labeled substrate, collection of breath samples, measurement of ^{13}C enrichment in breath CO_2 and the calculation of an end result.

Preparation of the patient

In general, tests will be performed in the fasting state and the patient should be at a low and stable level of natural ^{13}C abundance. Therefore, the patient must be instructed to avoid eating ^{13}C enriched foods such as corn products, cane sugar, pineapple and tequila the last days before the test and to come to the clinic fasted. In certain cases (^{13}C Lactose-Ureide breath test) the patient must be pretreated with unlabeled substrate to stimulate the involved enzyme system.

Administration of 13C labeled substrate

The test substrate may be administered as a simple solution in water with or without a standardized test meal. Sometimes it needs to be incorporated into a specific ingredient of the meal. The test meal and the dose of substrate may be different for adults and children.

Collection of breath samples

Every protocol has its own time schedule of breath collections. The number of samples may be as small as 2 or more than 20. To define the ^{13}C enrichment in breath CO_2, it is also necessary to obtain at least two breath samples before the ingestion of the ^{13}C substrate to determine the natural background of ^{13}C abundance. The methodology of collecting breath samples is dependent on the technology to determine the ^{13}C enrichment. The protocols are based on Continuous Flow Isotope Ratio Mass Spectrometry as the analytical technique. In this case breath samples are simply blown through a straw into special 10 ml gas collection tubes that directly fit into the sample tray of the instruments. In case of Infrared technology special bags provided by the instrument manufacturer must be used.

Measurement of ^{13}C enrichment

To determine the ^{13}C abundance in breath CO_2 you need the availability of Isotope Ratio Mass Spectrometry (IRMS) or specialized Infrared instrumentation. The protocols are based on Isotope Ratio Mass Spectrometry. For a number of tests (Aminopyrine, Methacetin, Urea) Infrared Spectroscopy has proven to be a valid alternative analytical technique. For other tests Infrared technology has not yet been validated so far. In principle the test substrate is not a determinant of the validity of the anlalytical technique. It is the level of ^{13}C enrichment that determines the analytical requirement. Validation of Infrared analysis for other application is recommended, as it is recommended to validate any breath test in your own clinical laboratory. You may have instrumentation available or contact a service center for the analyses.

Calculation of the end result

For some tests the only calculation needed is the subtraction of the natural background value from the measured value at a defined time. In other cases it is necessary to calculate the amount of ^{13}C that is recovered in breath during the experimental period. In a third type of application the time course of the enrichment appearance is of importance requiring calculation of the rate of appearance.

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Applications

In the present update the following tests have been described:

Table of contents of applications

Literature

Included is a list of literature references that will introduce you to the most important articles describing aspects of the different tests described in the protocols.

Note

Great care has been taken over the composition of the text, figures and tables. The possibility of errors however, cannot be excluded completely. Therefore Campro Scientific GmbH and the authors cannot accept any legal or other liability with respect to incorrect details and their consequences. The authors would be grateful to receive suggestions for improvements and information about errors.

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Test Protocols Intestine

1. Brush Border Enzymes
Natural Enriched ^{13}C-Lactose Breath Test

Principle

^{13}C-Lactose contains one or more carbon labeled with the non-radioactive isotope ^{13}C.
The ^{13}C-Lactose generally used for breath testing is labeled through a natural process. Carbon atoms in corn (a C-4 plant) have a higher abundance of ^{13}C than those in C-3 plants being the major natural food sources in humans. When corn is fed to cows the milk components become enriched in ^{13}C.
The Lactose isolated from this milk contains approximately 1.097% ^{13}C, whereas the mean ^{13}C content in breath CO_2 in Europeans is approximately 1.082%. After oral administration, ^{13}C-Lactose passes the stomach and is digested in the small intestine to a certain extent of ^{13}C-Glucose and ^{13}C-Galactose, which are effectively absorbed by the intestine. ^{13}C-Galactose is rapidly converted to ^{13}C -Glucose in the liver. Glucose is oxidized to a large extent. The kinetics of appearance of ^{13}C in breath CO_2 reflects the rate of intestinal digestion of lactose.

Applicability of ^{13}C-Lactose Ureide Breath Test

^{13}C-Lactose Breath Test has so far been applied to adults and children.

Applications

^{13}C-Lactose Breath Test is used to detect impaired digestion of lactose by comparison with a control range.

Protocol

Adults: The ^{13}C-Lactose Breath Test is performed after an overnight fast.
A dose of 50 g naturally enriched ^{13}C-Lactose is administered orally, dissolved in 250 ml water. Breath samples are collected before (2x) and every 30 minutes for 240 minutes (4 h) after ingestion of the ^{13}C-Lactose. ^{13}C enrichment in breath CO_2 is determined by Isotope Ratio Mass Spectrometry (IRMS). The cumulative percentage ^{13}C recovered in breath CO_2 after 4 hours is considered as the diagnostic parameter.

Children: a dose of 2 g/kg with a maximum of 50 gram naturally enriched ^{13}C-Lactose is used for children. The same schedule for breath collections can be applied.

Interpretation of test results

It is advised to obtain your own internal control values. Generally a cut-off value of 12 % for the 4 hours cumulative recovery may serve as a starting point in the case of adults and children. Values below 12% indicate maldigestion of lactose. It is advised to combine the ^{13}C-Lactose with the H_2 Breath Test, which is performed simultaneously using the same dose of 2 g/kg or 50 g ^{13}C-Lactose. In case one of the tests is positive, this is more representative of low lactase activity (sensitivity 85%).

Precautions

No contra-indications for the ^{13}C-Lactose Breath Test test have been described so far. Since the test is using a loading dose of lactose, intestinal complaints including diarrhea are to be expected in maldigesting patients.

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Summary

	Dose	Samples	
Adults	50 gram naturally enriched ^{13}C-Lactose	2	Before administration
		8	Every 30 minutes for 240 minutes after administration (4 hours)
Children	2 g/kg body weight with a maximum of 50 gram naturally enriched ^{13}C-Lactose	2	Before administration
		8	Every 30 minutes for 240 minutes after administration (4 hours)

Recent developments

The outcome of the ^{13}C-Lactose Breath Test is affected by the degree of glucose oxidation and the degree of $^{13}CO_2$ production due to fermentation of nondigested Lactose. Improved diagnosis is obtained by measurement of ^{13}C enrichment of plasma glucose (literature reference 4) in particular when 2H-Glucose is administered simultaneously to correct for gastric emptying and glucose metabolism (literature reference 1).

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2. Orocecal Transit Time
^{13}C-Lactose Ureide Breath Test

Principle
^{13}C-Lactose Ureide contains urea molecule labeled with the non-radioactive isotope ^{13}C attached to an unlabeled Lactose molecule. After oral administration ^{13}C-Lactose Ureide is not absorbed in the small intestine and is transferred to the colon. ^{13}C-Lactose Ureide is fermented by bacterial enzymes, splitting the bond between carbohydrate and urea. The released ^{13}C-Urea is then converted to ammonia and $^{13}CO_2$, which is absorbed and excreted in the breath. The start of appearance of ^{13}C in breath CO_2 reflects the entrance of ^{13}C-Lactose Ureide in the colon and therewith the orocecal transit time (OCTT).

Applicability of ^{13}C-Lactose Ureide Breath Test
^{13}C-Lactose Ureide Breath Test has so far been applied to adults and children.

Applications
^{13}C-Lactose Ureide Breath Test is used to detect accelerated or prolonged intestinal transit by comparison with a control range. The result reflects the orocecal transit time, which may be prolonged by intestinal dysmotility or reduced by nutrional factors or drugs.

Protocol
Adults: The subjects are pre-treated with 1 gram unlabeled Lactose Ureide during the evening preceding the study day to stimulate bacterial enzyme production. The ^{13}C-Lactose Ureide Breath Test is performed after an overnight fast. A dose of 500 mg ^{13}C-Lactose Ureide is administered orally after dissolution in about 100 ml water or cold tea after a standardized breakfast (one wheat flour roll, marmelade, butter and coffee). Breath samples are collected before (2x) and every 30 min for 600 minutes (10 h) after ingestion of the ^{13}C-Lactose Ureide. A light lunch containing no ^{13}C rich ingredients can be supplied about 4 hours after adminstation of ^{13}C-Lactose Ureide. ^{13}C enrichment in breath CO_2 is determined by Isotope Ratio Mass Spectrometry (IRMS). The OCTT is calculated as the time interval between ingestion of ^{13}C-Lactose Ureide and the observation of a rise in ^{13}C in breath CO_2 of 2 delta values or more followed by a sustained rise of enrichment.

Children: Pre-treatment is performed with 500 mg unlabeled Lactose Ureide. A dose of 250 mg ^{13}C-Lactose Ureide is used for the test. The test meal can be adapted to 200 ml chocolate milk. The same time schedule for breath collections can be used reducing the end point to 600 minutes (10 h)

Interpretation of test results
It is advised to obtain your own internal control values. Literature data are still scarce. A normal range of 290 ± 60 min has been described for OCTT in adults as well as values between 165 and 390 min for children.

Precautions
Bacterial enzyme activity must be stimulated by the pre-treatment protocol. No drugs or food ingredients are allowed during the test that may affect the intestinal transit of the test meal including ^{13}C-Lactose Ureide.

Summary

	Dose	Samples	
Adults	1 gram (pre-treatment) unlabeled Lactose Ureide, 500 mg ^{13}C-Lactose Ureide	2	Before administration
		20	Every 30 minutes for 600 minutes after administration (10 hours)
Children	500 mg (pre-treatment) unlabeled Lactose Ureide, 250 mg ^{13}C-Lactose Ureide	2	Before administration
		20	Every 30 minutes for 600 minutes after administration (10 hours)

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3. Bacterial Overgrowth
^{13}C-Xylose Breath Test

Principle
^{13}C-Xylose is a labeled monosaccharide which is only partially absorbed from the small intestine. The non absorbable part is fermented by colonic bacteria producing $^{13}CO_2$. The presence of xylose fermenting bacteria in the small intestine leads to an early rise in $^{13}CO_2$ in breath. The degree of ^{13}C enrichment reflects the degree of bacterial overgrowth.

Applicability of ^{13}C-Xylose Breath Test
So far only a limited number of applications have been decribed both in adults and in children.

Applications
The ^{13}C-Xylose Breath Test result reflects small intestinal bacterial mass flow. Correlations have been shown with bacterial cultures in intestinal aspirates.

Protocol
Adults: The ^{13}C-Xylose Breath Test is performed after an overnight fast. A dose of 250 mg ^{13}C-Xylose is administered orally after dissolution in 50 ml water. Breath samples are collected before (2x) and every 30 minutes for 180 minutes (3 h) after ingestion of the ^{13}C-Xylose. ^{13}C enrichment in breath CO_2 is determined by Isotope Ratio Mass Spectrometry (IRMS). The ^{13}C enrichment after the 180 minutes collection period is used as the diagnostic parameter.

Children: A dose of 50 mg is used for children in 5 ml water or in capsules together with 30 ml water. The same time schedule for breath collections can be used. The maximum enrichment has been used as the diagnostic parameter.

Interpretation of test results
It is advised to obtain your own internal control values. The number of published data is too small to indicate a general cut off value.

Precautions
Since ^{13}C-Xylose is partially malabsorbed, colonic bacteria also produce $^{13}CO_2$. Therefore the small intestinal fermentation should be detected at the earliest time point. However, ^{13}C-Xylose is also partly absorbed and metabolically oxidised into $^{13}CO_2$. This probably explains the control range. Patients with abdominal complaints may generally suffer of malabsorption phenomena and motility disorders. The latter may cause intersubject variation in the rate of Xylose delivery to the fermenting bacteria. A delayed response may be caused by delayed gastric emptying and slow intestinal transit and be interpreted as colonic response. Vice versa increased intestinal motility may cause a rapid colonic response which may be confused with small intestinal response. Furthermore the bacteria should contain active carbohydrate fermenting enzymes.

Summary

	Dose	Samples	
Adults	250 mg ^{13}C-Xylose	2	Before administration
		6	Every 30 minutes for 180 minutes after administration (3 hours)
Children	50 mg ^{13}C-Xylose	2	Before administration
		6	Every 30 minutes for 180 minutes after administration (3 hours)

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Literature

Intestine

1. Brush Border Enzymes
Natural Enriched ^{13}C-Lactose Breath Test

Recommended literature

1. Romagnuolo J, Schiller D, Bailey RJ. Using breath tests wisely in a gastroenterology practice: an evidence-based review of indications and pitfalls in interpretation. Am J Gastroenterol. 2002 May;97(5):1113-26. Review.

2. Vonk RJ, Stellaard F, Priebe MG, Koetse HA, Hagedoorn RE, De Bruijn S, Elzinga H, Lenoir-Wijnkoop I, Antoine JM. The ^{13}C/2H-glucose test for determination of small intestinal lactase activity. Eur J Clin Invest. 2001 Mar;31(3):226-33.

3. Stellaard F, Koetse HA, Elzinga H, Boverhof R, Tjoonk R, Klimp A, Vegter D, Liesker J, Vonk RJ. ^{13}C-carbohydrate breath tests: impact of physical activity on the rate-limitingstep in lactose utilization. Scand J Gastroenterol. 2000 Aug;35(8):819-23.

4. Koetse HA, Vonk RJ, Pasterkamp S, Pal J, de Bruijn S, Stellaard F. Variations in colonic H2 and CO2 production as a cause of inadequate diagnosis of carbohydrate maldigestion in breath tests. cand J Gastroenterol. 2000 Jun;35(6):607-11.

5. Vonk RJ, Lin Y, Koetse HA, Huang C, Zeng G, Elzinga H, Antoine J, Stellaard F. Lactose (mal)digestion evaluated by the ^{13}C-lactose digestion test. Eur J Clin Invest. 2000 Feb;30(2):140-6.

6. Koetse HA, Stellaard F, Bijleveld CM, Elzinga H, Boverhof R, van der Meer R, Vonk RJ, Sauer PJ. Non-invasive detection of low-intestinal lactase activity in children by use of a combined $^{13}CO_2/H_2$ breath test. Scand J Gastroenterol. 1999 Jan;34(1):35-40.

7. Murray RD, Boutton TW, Klein PD, Gilbert M, Paule CL, MacLean WC Jr. Comparative absorption of [^{13}C]glucose and [^{13}C]lactose by premature infants. Am J Clin Nutr. 1990 Jan;51(1):59-66.

8. Hiele M, Ghoos Y, Rutgeerts P, Vantrappen G, Carchon H, Eggermont E. $^{13}CO_2$ breath test using naturally ^{13}C-enriched lactose for detection of lactase deficiency in patients with gastrointestinal symptoms. J Lab Clin Med.1988 Aug;112(2):193-200.

9. MacLean WC Jr, Fink BB, Schoeller DA, Wong W, Klein PD. Lactose assimilation by full-term infants: relation of [^{13}C] and H_2 breath tests with fecal [^{13}C] excretion. Pediatr Res. 1983 Aug;17(8):629-33.

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2. Orocecal Transit Time
^{13}C-Lactose Ureide Breath Test

Recommended literature

1. Christian M, Morrison D, Dodson B, Preston T, Amarri S, Franchini F, Edwards C, Weaver L. Measurement of oro-cecal transit time in young children using lactose [^{13}C] ureide requires further validation. J Pediatr Gastroenterol Nutr. 2002 May;34(5):570-1; author reply 571.

2. Van Den Driessche M, Van Malderen N, Geypens B, Ghoos Y, Veereman-Wauters G.Lactose-[^{13}C]ureide breath test: a new, noninvasive technique to determine orocecal transit time in children. J Pediatr Gastroenterol Nutr. 2000 Oct;31(4):433-8.

3. Jackson AA, Bundy R, Hounslow A, Murphy JL, Wootton SA.Metabolism of lactose-[^{13}C]ureide and lactose-[^{15}N,^{15}N]ureide in normal adults consuming a diet marginally adequate in protein. Clin Sci (Lond). 1999 Nov;97(5):547-55.

4. Geypens B, Bennink R, Peeters M, Evenepoel P, Mortelmans L, Maes B, Ghoos Y, Rutgeerts P. Validation of the lactose-[^{13}C]ureide breath test for determination of orocecal transit time by scintigraphy. J Nucl Med. 1999 Sep;40(9):1451-5.

5. Morrison DJ, Dodson B, Preston T. Measurement of urinary total ^{13}C and ^{13}C urea by isotope ratio mass spectrometry after administration of lactose [^{13}C]-ureide. Rapid Commun Mass Spectrom. 1999;13(13):1252-6.

6. Morrison DJ, Zavoshy R, Edwards CA, Dodson B, Preston T, Weaver LT. Lactose [^{13}C]Ureide as a marker for colonic fermentation and the deconvolution of a complex $^{13}CO_2$ breath test curve. Biochem Soc Trans. 1998 May;26(2):S184.

7. Ruemmele FM, Heine WE, Keller KM, Lentze MJ. Metabolism of glycosyl ureides by human intestinal brush border enzymes. Biochim Biophys Acta. 1997 Aug 29;1336(2):275-80.

8. Wutzke KD, Heine WE, Plath C, Leitzmann P, Radke M, Mohr C, Richter I, Gulzow HU, Hobusch D. Evaluation of oro-coecal transit time: a comparison of the lactose-[^{13}C,^{15}N]ureide $^{13}CO^{2}$- and the lactulose H_2-breath test in humans. Eur J Clin Nutr. 1997 Jan;51(1):11-9.

9. Heine WE, Berthold HK, Klein PD. A novel stable isotope breath test: ^{13}C-labeled glycosyl ureides used as noninvasive markers of intestinal transit time. Am J Gastroenterol. 1995 Jan;90(1):93-8.

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3. Bacterial Overgrowth
^{13}C-Xylose Breath Test

Recommended literature

1. Dellert SF, Nowicki MJ, Farrell MK, Delente J, Heubi JE. The ^{13}C-xylose breath test for the diagnosis of small bowel bacterial overgrowth in children. J Pediatr Gastroenterol Nutr. 1997 Aug;25(2):153-8.

2. Lim H, Wagner DA, Toskes PP. ^{13}C-xylose breath test for bacterial overgrowth. Gastroenterology 1993 April;104(4): A259

3. Valdovinos MA, Camilleri M, Thomforde GM, Frie C. Reduced accuracy of ^{14}C-D-xylose breath test for detecting bacterial overgrowth in gastrointestinal motility disorders. Scand J Gastroenterol. 1993 Nov;28(11):963-8.

4. Chang CS, Chen GH, Kao CH, Wang SJ, Peng SN, Huang CK, Poon SK. Increased accuracy of the carbon-^{14} D-xylose breath test in detecting small-intestinal bacterial overgrowth by correction with the gastric emptying rate. Eur J Nucl Med. 1995 Oct;22(10):1118-22.

5. Stotzer PO, Kilander AF. Comparison of the 1-gram (^{14})C-D-xylose breath test and the 50-gram hydrogen glucose breath test for diagnosis of small intestinal bacterial overgrowth. Digestion. 2000;61(3):165-71.

6. King CE, Toskes PP, Guilarte TR, Lorenz E, Welkos SL. Comparison of the one-gram d-[^{14}C]xylose breath test to the [^{14}C]bile acid breath test in patients with small-intestine bacterial overgrowth. Dig Dis Sci. 1980 Jan;25(1):53-8.

7. King CE, Toskes PP. Breath tests in the diagnosis of small intestine bacterial overgrowth. Crit Rev Clin Lab Sci. 1984;21(3):269-81. Review.

8. Lewis SJ, Young G, Mann M, Franco S, O'Keefe SJ. Improvement in specificity of [^{14}C]d-xylose breath test for bacterial overgrowth. Dig Dis Sci. 1997 Aug;42(8):1587-92.

9. Rumessen JJ. [^{14}C]D-xylose breath test for small intestinal bacterial overgrowth. Gastroenterology. 1989 Jan;96(1):273-4.

10. Riordan SM, McIver CJ, Duncombe VM, Bolin TD, Thomas MC. Factors influencing the 1-g ^{14}C-D-xylose breath test for bacterial overgrowth. Am J Gastroenterol. 1995 Sep;90(9):1455-60.

11. King CE, Toskes PP. Comparison of the 1-gram [^{14}C]xylose, 10-gram lactulose-H2, and 80-gram glucose-H2 breath tests in patients with small intestine bacterial overgrowth. Gastroenterology. 1986 Dec;91(6):1447-51.

12. Schneider A, Novis B, Chen V, Leichtman G. Value of the ^{14}C-D-xylose breath test in patients with intestinal bacterial overgrowth. Digestion. 1985;32(2):86-91.

13. King CE, Toskes PP, Spivey JC, Lorenz E, Welkos S. Detection of small intestine bacterial overgrowth by means of a ^{14}C-D-xylose breath test. Gastroenterology. 1979 Jul;77(1):75-82.

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