Correlation of bowel symptoms with colonic transit, length, and faecal load in functional faecal retention

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ABSTRACT

Introduction: Abdominal pain, bloating, and defecation disturbances are common complaints in gastrointestinal functional disorders. This study explores whether bowel symptoms are correlated to colon transit time (CTT), faecal loading (coprostasis), and colon length; and whether prokinetic intervention can reduce CTT, faecal retention, and symptoms.

Methods: This observational and interventional study includes 281 patients, and 44 asymptomatic controls. Evaluations included symptoms, physical signs, CTT, faecal loading, barium enema, endoscopy, sonography, anal manometry and biochemistry. Interventions included a low-fat, high-fiber diet, cisapride or domperidone, and exercise for a mean of 21.6 months.

Results: The mean CTT was 40.71 h in patients vs 24.75 h in controls ($p = 0.013$). In patients, faecal loading was significantly greater than in controls ($p < 0.001$). Bloating correlated significantly positively with CTT ($r = 0.174$, $p = 0.009$), and faecal load. Abdominal pain correlated significantly positively with distal faecal loading ($r = 0.151$; $p = 0.036$). The mean CTTs in patients with zero to four colon redundancies were: 36.26 h, 43.80 h, 41.65 h and 52.27 h, respectively ($p = 0.030$), and symptoms increased significantly with increase in the number of redundancies ($p < 0.001$). A subgroup of patients ($n = 90$) with normal CTTs (≤ 24.75 h) had significantly higher faecal loading compared to controls ($p = 0.033$). Factor analysis showed that bloating correlated significantly with abdominal pain and defecation rate ($p < 0.05$) and that CTT and faecal load correlated inversely with daily defecation rate, ease, incompleteness, repetitiveness, and faecal consistency. Intervention significantly reduced CTT, faecal loading, bloating, abdominal pain, and improved defecation patterns ($p < 0.05$).

Conclusions: Faecal retention with or without increased CTT, caused bloating, abdominal pain and altered defecation patterns in patients with bowel symptoms. An elongated colon aggravated the symptoms. Measurements of CTT, faecal load and the number of colon redundancies can be useful guides in clinical practice. Prokinetic intervention reduces abdominal and anorectal symptoms, and improves quality of life.

Abdominal pain, bloating, and defecation disorders are common complaints in constipation and irritable bowel syndrome [1]. The major functions of the colon are to conserve water, to allow bacteria to split dietary fibre into absorbable nutrients (with gas production), and to store, propel, and expel faeces. Balloon distension of different parts of the colon will cause abdominal pain [2], suggesting that the faecal content and gas in the colon may give rise to abdominal symptoms [3]. Functional abnormalities are measured by colonic transit time (CTT) [4] and the amount of faeces can be quantified on an abdominal radiograph [5]. The length of the colon has been suggested to contribute to functional constipation [6].

The present study explores whether abdominal and anorectal symptoms are correlated with CTT and faecal loading (coprostasis). We also investigate the impact of colonic length. Finally, we ask, whether an intervention can reduce CCT and faecal loading, eliminate abdominal symptoms, and restore normal defecation patterns.

MATERIAL AND METHODS

Between June 19, 1997 and August 31, 2004, 281 referred patients were included in an observational and interventional study approved by a local ethical and research committee and our institutional board. The criteria for inclusion of patients were a suspicion of constipation with abdominal symptoms and defecation disorders. A previous standardized questionnaire was completed for each patient, reporting the presence or not of a symptom [3] (Figure 1). Anamnestic data included previous or chronic diseases, profession, and employment status. The influence of bowel function on the quality of life (QoL) was assessed with a numeric box scale that ranged from zero (large influence on daily life) to ten (no influence). Each patient underwent a physical examination, and an ano-rectoscopy. A control group was recruited from a random selection of 372 people over 18 yr old, in the National Civil Register. Screening excluded those with gastrointestinal complaints, those who took laxatives or strong analgesics, and those who had previous abdominal surgery. Forty-four people (equal numbers of males and females) were then included in this and a simultaneous study [7] and investigated between January 24, 2000 and December 11, 2001.

COLONIC STUDIES

For one week before the study, patients refrained from using laxative. A capsule containing 24 radio opaque markers (Sitzmark, Kon-

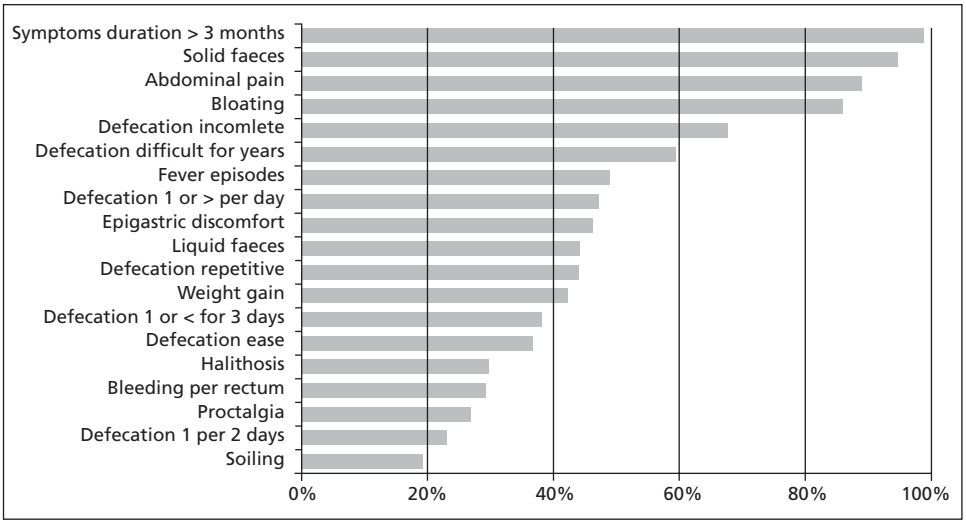

Figure 1. Frequencies of patients' individual reported abdominal and anorectal symptoms.

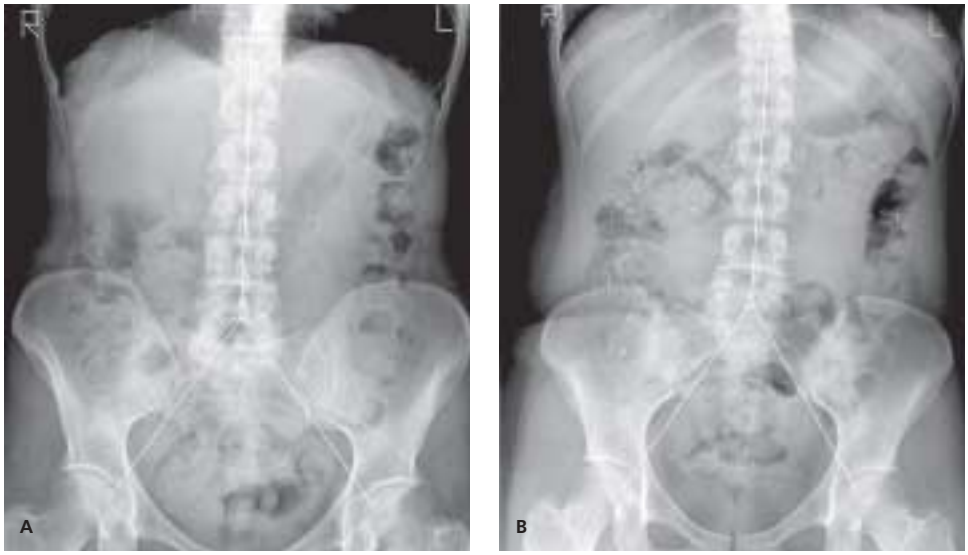

Figure 2. A. Marker study X-ray taken 48 h after ingestion of 24 markers. Two markers and faecal retention are visible in the colon (segmental faecal loading scores 3 + 3 + 3 = 9) in a 55-year old woman, showing faecal retention with a normal transit time (CTT). **B**. Marker study X-ray taken 48 h after ingestion of 24 markers. All markers and faecal retention are visible in the colon (faecal loading scores 3 + 3 + 3 = 9) in a 20 year old woman, showing faecal retention with a prolonged transit time (CTT).

syl Pharmaceutical Inc., Forth Worth, Texas, U.S) was ingested by each patient, and abdominal X-rays were taken after 48 h and 96 h [4]. Abdominal X-rays were divided into three segments in a reversed Y design (*modified from* [5]) that included the right and left hemicolons and the rectosigmoid (Figure 2). The total number, n, of markers was counted in each segment, and CTT was calculated from the following equation:

$$CTT\ (hours) = (48/n) \times (n48 + n96)$$

where n48 and n96 were the numbers of markers detected at 48 and 96 hrs after ingestion of n = 24 markers [8]. Also, faecal load in each segment was estimated with a score from zero to three, where zero signified no faeces visible, one signified slight, two signified moderate, and three signified severe faecal loading (i.e. a total faecal load score from zero to nine could be obtained). The CTT and faecal loading scores were also estimated for the controls. The X-ray images were examined by observers, who were unaware of the clinical course of the patients. After intervention (see below), the colonic marker study was repeated.

A barium enema of the colon was used to picture the anatomy and pathological changes. Colonic redundancies were recorded according to the following criteria: A sigmoid loop rising over a line between the iliac crests [9], a transverse colon below the same line and extra loops at the left and right colon flexure, are each considered to be redundant. A fully developed dolichocolon (elongated colon) occurs when all redundancies are present simultaneously [9,10]. Endoscopy was used only in patients with alarm symptoms.

ANORECTAL PHYSIOLOGIC TESTING

A saline perfused polyvinyl catheter with four channels and pressure transducers was connected to a computer recording system (Medical Equipment, Jyllinge, Denmark). A standardized procedure was followed [11].

ULTRASONOGRAPHY

An abdominal ultrasound was performed on patients, who had not previously undergone cholecystectomy.

CLINICAL BIOCHEMISTRY

Blood samples were analyzed for P-glucose, -calcium, -orosomucoid, -CRP, cholesterol (HDL, LDL, VDL), -triglyceride, -coeliacic antibodies, and thyroid parameters.

INTERVENTION

The patients were treated with meal planning and a diet low in fat and rich in fibre (dietician), as advocated by the Danish Nutritional Council. The diet was supplemented with 10 to 20 g/day of ispagula husk (Ratje Frøskaller, Kastrup, Denmark) and 10-20 mg cisapride or 10 mg of domperidone, both up to three doses per day. The patients were encouraged to perform at least 30 min a day of physical activity. Individual treatments continued until patients reported some relief from their symptoms. At this time, CTT, faecal loading, symptoms and QoL were reassessed. Patients refractory to the treatment were offered transanal irrigation or surgery was considered.

STATISTICAL ANALYSIS

The data was compiled in a database prepared in cooperation with UNI-C, the Danish IT Centre for Research and Education in Copenhagen (statistician Jesper Lund), who subsequently carried out the statistical analyses, using SPSS version 14. The frequencies of symptoms, physical signs, and investigations were defined as the percentage of all patients with symptoms, who responded affirmatively. A Mann-Whitney U-test was used to compare CTT and faecal loadings between patients and controls. A p-value of 0.05 or less was considered significant. Correlations between CTT and faecal loading scores, and between the abdominal and anal symptoms were measured with Spearmans rho (r). Findings of important symptoms, signs, and investigations were also cross tabulated. Multiple statistical testing could imply a risk of mass significance. However, this study tested specific hypotheses or explored for possible coexistence. The statistical tests were performed with different variables and not by multiple comparisons of overlapping groups. In order to further minimizing the risk, the actual p-values have been shown for all tests performed, and in cases where these are close to the chosen level of significance, the results are interpreted with caution.

Principal component analysis (factor or cluster analysis) was chosen for exploring correlations. Although factor analysis is not primarily designed for binary variables, it can be used in this context. The method analyzes the pattern of correlation coefficients between the variables and combines groups of highly correlated variables into a smaller number of independent (uncorrelated) new variables (factors) that explain a major part of the variation [12, 13]. Thus, the correlation of a variable (symptom, sign, or investigation) with an individual factor is expressed as a factor loading or correlation coefficient, with a value between -1 and +1; the greater the numeric correlation, the greater the association to the factor; factor loadings less than 0.3 were considered insignificant.

The proportional decline in colonic markers was determined between 48 h to 96 h in order to estimate the marker elimination rate. The elimination rates were then related to the efficiency of the treatment intervention. The elimination rate was calculated for each patient as follows:

Elimination rate = (n48 – n96)/n48

where n48 and n96 were the numbers of markers detected on the X-ray film taken at 48 h and 96 h, respectively, after ingestion. The elimination rate was correlated to abdominal and anorectal symptoms.

RESULTS

Of the 281 patients included in this study, 267 patients were analyzed, 230 women, 37 men, mean age 50.8 yr, range 18-86). Forty-four randomely selected persons (mean age 43.4 yr, range 21-67 yr) constituted the control group, with a significantly lower mean age compared to the patients (p = 0.003, Mann-Whitney U-test). The main reasons for patient exclusion were that they did not fulfil the inclusion criteria, they did not attend the scheduled investigations or follow-up, they did not want to take medication, or they did not adhere to the prescribed diet.

The symptom frequencies are shown in Figure 1. The most common abdominal symptoms were pain and bloating. Most patients reported solid stools, but liquid faeces were not uncommon (44.1%). Many patients reported one or more daily defecations (47.2%) or repetitiveness (44.0%). The dominant physical signs were right iliac fossa tenderness (66.2%), palpable faecal mass (faecal reservoir) (39.5%), and meteorism (60.5%). Tenderness in the left iliac fossa was found in 19.5%, and a mass on the left side was found in 3.8% of the patients. Ano-rectoscopy showed a reservoir of solid faeces in 41.2% of patients and haemorrhoids of grade 2 or more in 21.4% of patients. Five polyps were identified, and no malignancies were found.

The marker study showed that the mean colonic transit time was 40.71 hr (range 0–96 h) in 225 patients compared to 24.75 h (range 0-71 h) in 44 controls (p = 0.013, Mann-Whitney U-test). Females tended to have longer mean CCTs than males; this was true in patients (41.35 h vs 36.88 h), and in controls (29.77 h vs 19.73 h), although the differences were not statistically significant (p > 0.05). Likewise, the faecal loading scores did not differ significantly between women and men in the control group (total: 4.5 vs 4.1; p = 0.144). However, differences in mean faecal loading scores between patients and controls were statistically significant in all colonic segments at 48 h (right: 2.3 vs 1.8, left: 2.1 vs 1.3, distal: 1.8 vs 1.3, total: 6.2 vs 4.4, Mann-Whitney test, p < 0.001), and at 96 h (p < 0.001). In 194 patients, there were no statistical significant differences in mean faecal loading scores between 48 h and 96 h (right: 2.3 vs 2.4, left: 2.1 vs 2.2, distal: 1.8 vs 1.9 and total: 6.2 vs 6.5, all p > 0.05, Wilcoxon signed ranked test). Correlation analyses showed that CTT was statistically significantly positively correlated with segmental loading scores at 48 h (right: r = 0.428, left: r = 0.548, distal: r = 0.575, total: r = 0.610, p < 0.001) and at 96 h (right: r = 0.380, left: r = 0.469, distal: r = 0.563, total: r = 0.563; p < 0.001).

Bloating correlated significantly positively with CTT (222 patients, r = 0.174; p = 0.009), with faecal loading in the right colon at 48h (249 patients, r = 0.174, p = 0.006), and with total faecal load (r = 0.128, p = 0.044). Abdominal pain was significantly positively correlated to distal faecal loading at 48 h (250 patients, r = 0.141, p = 0.026) and at 96 h (192 patients, r = 0.151, p = 0.036). Also, CTT correlated positively with infrequent defecation (r = 0.428, p < 0.001) and negatively with defecation ease (r = -0.483, p < 0.001), repetitiveness (r = -0.264, p < 0.001) and liquid faeces (r = -0.290, p < 0.001). Segmental and total faecal loading were significantly correlated in the same way with these clinical parameters.

Patients were stratified into a subgroup (n = 90, mean age 50.6, range 18-65 yr), having a CTT ≤24.75 h (mean of control subjects). Table 1 shows that these patients had a statistically significant increase in faecal loading scores compared to the controls. This subgroup of patients had a significantly higher mean age than the controls (50.6 yr vs 43.4 yr, p = 0.008, Mann-Whitney U-test).

The data was analyzed further by correlating CTT and faecal loading with the physical signs. CTT was significantly positively correlated with a palpable mass in the left fossa (220 patients, r = 0.240, p < 0.001) and with meteorism (217 patients, r = 0.197; p = 0.030). Similarly, left faecal load was significantly positively correlated to a palpable mass in the left fossa (189 patients) at 48 h and 96 h (r = 0.172; p = 0.018); correlations to a right sided palpable mass were insignificant (p > 0.05).

Factor analysis was able to reduce the main variables to six factors with an eigenvalue greater than one, which explained 65% of the variance (Table 2). Each coefficient (loading factor) expresses the correlation between a variable and a particular factor. CTT correlated positively with factor I (225 patients, r = 0.354, p < 0.001), factor V (r = 0.158, p < 0.001), and factor VI (r = 0.389, p < 0.001). Factor I was correlated positively to right sided colonic faecal load at 48 h (r = 0.223, p < 0.001), left-sided colonic faecal load (r = 0.242, p < 0.001), distal faecal load (r = 0.146, p < 0.001) and to total load

Table 1. Mean faecal loading scores at 48 hours after marker ingestion.

Colon segments	All patients (n = 252)	Subgroup (n = 90)	Controls (n = 44)	p-value
Right	2.3	2.0	1.8	0.034 (S)
Left	2.1	1.7	1.3	0.001 (S)
Distal	1.8	1.2	1.3	0.655 (NS)
Total	6.2	4.9	4.4	0.033 (S)

Comparisons are between a subgroup of patients with CTT ≤ 24.75 h and healthy controls, evaluated by the Mann-Whitney U-test. S = statistically significant; NS = not significant.

Table 2. Factor loadings[1] in factors of symptoms.

Symptoms	I	II	III	IV	V	VI
Halitosis					0.668	
Epigastric discomfort					0.491	
Bloating	0.644		0.357	0.353		
Abdominal pain				0.848		
Proctalgia	0.596			0.369		
Defecation 1 or more per day		–0.308	0.758			
Defecation 1 per 2 days			0.845			
Defecation 1 or less per 3 days	0.360		0.705			
Defecation ease		0.598				
Defecation incomplete		0.775				
Defecation repetitive		0.895				
Faeces solid	0.597	0.399	0.332			
Faeces liquid		0.662				
Soiling	0.432	0.353				
Rectal bleeding	0.715					
Fever episodes					0.708	
Weight gain			0.310	0.341	0.610	
Defecation difficult for years	0.770					0.914

1) Factor analysis used varimax rotation with Kaiser normalization. Factors are described in the text. Factor loadings < 0.300 are not shown (see Statistics)

Figure 3. Barium enema showing a colon elongatum (dolicholon) in a 36 year old woman with redundancies in the right, left and distal part of the colon.

(r = 0.236, p < 0.001); similar correlations were proven at 96 h. Factor II was negatively correlated with CTT (r = -0.496, p < 0.001) and faecal load in all colonic segments at 48 h and 96 h: that is right 48 h (*r* = -0.390, p < 0.001).

Two hundred and thirty-six patients (206 females, 30 males) had a barium enema study of the colon with special reference to the number of redundancies (Figure 3). A redundancy localized to the sigmoideum occurred in 72.5% of all patients, to the splenic flexure in 26.6%, to the tranverse colon in 33.9% and to the right hepatic flexure in 18.6%. Coecal dystopia was seen in 8.1%. The mean CTT in patients without redundancies was 36.26 h; with one redundancy, 43.80 h; with two redundancies, 41.65 h; and with three to four redundancies, 52.27 h. A Jonckheere-Terpstra test showed statistical significant differences in CTT between the four levels of redundancies (p = 0.030). A separate analysis showed a significant positive correlation between CTT and a redundant sigmoid, r = 0.147, p = 0.038). A significant increase in occurrence of the symptom variables bloating, abdominal pain and infrequent defecations was seen with and increased number of redundancies (n = 235, p < 0.01). The number of redundancies was not associated with defecation ease, incompleteness, repetitiveness and faecal consistency. Similar cross-tabulations of the physical signs did not show any significant correlations to colonic redundancies.

Leftsided colon diverticula were present in 20.5% of the patients (49/239), and right-sided diverticula were found in 7.6% (18/237) of the patients. Two patients had a stenosis and none had tumours. The occurrence of left-sided diverticula was significantly positively correlated to and increase in age (r = 0.144, p = 0.026, n = 239). No significant correlations were found in 211 patients between a prolonged CTT (≥24.75 h) or faecal loading and the occurrence of diverticula.

No significant correlations were found between a prolonged CTT or faecal loading and the occurrence of breast cancer, musculoskeletal diseases, or employment status. However, familial colorectal cancer occurred significantly more often in patients, who had a higher mean faecal load than the controls (p = 0.041, chi-square test). Moreover, patients who had previously had an appendectomy (n = 67) exhibited a significantly higher mean CTT (45.4 h, p = 0.051, Mann-Whitney U-test) compared to those who had not (n = 165, mean CTT = 36.3 h). There was no significant difference between the faecal loading scores for the two groups.

Gallstones were detected by ultrasonography in 31 females (16.5%) and five males (18.5%). Thirty-one patients had previously had a cholecystectomy. No significant correlations were proven between CTT or faecal loading and the occurrence of gallstones (r = 0.048, p = 0.484). In addition, clinical blood chemistry tests revealed no significant correlations between CTT or faecal loading and serum cholesterol levels.

The anorectal physiologic evaluation revealed a mean strain pressure of 62.14 cm H_2O (SD = 32.71 cm H_2O, (n =159) and a mean maximum squeeze pressure of 134.05 cm H_2O (SD = 57.10 cm H_2O), (n =166). The RAIR was present in 89.4% of the patients. The mean volume for the first sensation was 93.47 ml (SD = 56.31 ml). The mean modest urge volume was 128.72 ml (SD = 66.90 ml), and the mean maximum tolerable volume was 147.91 ml (SD = 68.62 ml). Correlation analysis between these variables and CTT showed a significant positive correlation with the volume of the first sensation (r = 0.196, p = 0.020, n = 140).

The mean intervention period was 21.6 months for 264 patients. Non-compliance for reassessments was due to various reasons, including personal, geographic, economic, family, or other disease. After intervention, the mean CTT was significantly reduced from 40.71 h (SD = 32.54 h) to 32.77 h (SD = 26.28 h), (p < 0.001, Wilcoxon's signed rank test). A paired analysis demonstrated similar significance. A comparison of the CTT between patients after treatment and controls showed no statistical significant difference (p = 0.075, Mann-Whitney U-test). After intervention, the faecal loading scores were also reduced significantly (p < 0.05, Wilcoxon test) in all segments of the colon. However, the mean faecal loading was heavier in patients after intervention compared to controls (6.2 vs 4.3, p < 0.001 Mann-Whitney U-test).

A treatment can influence the symptoms in four possible ways: a symptom may disappear, appear, still be present, or still be absent. Bloating and abdominal pain were reduced significantly and he defecation process was significantly improved overall (Table 3).

Table 3. Change (relief) in abdominal and anorectal symptoms after intervention.

	Disappeared		Still present		Still absent		Appeared		Total	
	%[1]	n	%[1]	n	%*	n	%*	n	%*	n
Bloating	37.3	79	51.9	110	9.9	21	0.9	2	100	212
Abdominal pain	48.4	104	42.3	91	8.8	19	0.5	1	100	215
Proctalgia	18.6	39	8.1	17	72.9	153	0.5	1	100	210
Defecation 1 or more per day	2.8	6	41.6	89	18.7	40	36.9	79	100	214
Defecation 1 per 2 days	18.2	39	6.5	14	63.1	135	12.1	26	100	214
Defecation 1 or less per 3 days	34.1	72	5.7	12	57.8	122	2.4	5	100	211
Defecation ease	3.0	6	32.0	64	24.5	49	40.5	81	100	200
Defecation incomplete	40.9	76	28.0	52	27.4	51	3.8	7	100	186
Defecation repetitive	29.4	55	12.8	24	54.5	102	3.2	6	100	187
Solid faeces	2.0	4	94.1	192	0	0	3.9	8	100	204
Liquid faeces	28.3	56	12.1	24	52.5	104	7.1	14	100	198

1) Percent changes in symptoms after intervention. All changes were significant with p < 0.001, evaluated by the McNemar test, except for defecation 1 per 2 days (p = 0.136) and solid faeces (p = 0.388).

Analyses of the subgroup of 90 patients with an initial CTT ≤ 24.75 h revealed that after intervention there were no significant changes in CTT or faecal loading. However, bloating disappeared in 50.0% of the patients (35/70; $p < 0.001$, Sign test) and abdominal pain disappeared in 57.1% (40/70; $p < 0.001$, Sign test). The intervention was followed by significantly more ease in defecation, and reduced incompleteness, repetitiveness, liquid faeces and proctalgia (all $p < 0.05$, Sign test).

The mean elimination rate of radio opaque markers (see Statistics) was 0.68 (68%) of markers eliminated in 74 patients who experienced a disappearance of abdominal pain after intervention, compared to 0.54 (54%) in 71 patients who still had pain ($p = 0.031$, Mann-Whitney U-test). Likewise, the elimination rate was 0.68 for patients who experienced the disappearance of bloating ($n = 60$) and 0.55 in patients ($n = 79$) who still reported bloating after intervention ($p = 0.059$, Mann-Whitney U-test). There were no significant correlations between elimination rates and any of the anal symptoms.

The quality of life in patients ($n = 272$) rose significantly from mean 3.68 to 5.13 (VAS 0-10, $p < 0.001$, Wilcoxon signed ranks test).

DISCUSSION

This study demonstrated that patients with bowel symptoms exhibited significant correlations of abdominal and anorectal symptoms with CTT and faecal loading. The patients were primarily females with an average CTT longer than that observed in men. It is difficult to define a normal transit time. It varies with the study method, the population under investigation, dietary intake, and physical activity. The normal transit time in this study (24.75 h in controls) is similar to that reported in other studies of healthy people [4, 14]. Single-marker ingestion was preferred here for better compliance by patients and multiple-marker ingestion for reduced radiation exposure for controls. This group was constituted by equal numbers of women and men to measure a physiologically normal CTT and estimate faecal load, with no significant differences in CTT and faecal load by gender. The patients exhibited a severe load of faeces in all colonic segments (faecal reservoirs) compared to the controls and this was a permanent condition. Also, CTT was significantly correlated with segmental loading scores at 48 h and 96 h. Thus, age seems to be an essential factor in functional faecal retention, since the controls had a lower age than the patients.

Bloating was significantly correlated with faecal loading in the right colon, total faecal load, and delayed CTT. This is consistent with the delay in the right colon CTT, recently reported [14]. Our identification of symptom clusters by factor analysis showed that bloating was substantially correlated to frequent or rare defecations, solid faeces, abdominal pain, proctalgia and right, left, and total faecal load. Also, in a recent study [3], factors showed clusters of upper and lower gastrointestinal symptoms. These and other new data [15] suggest that functional disorders may have a common ethiopathogenesis. In our study, ease of defecation, incompleteness, and repetitiveness with a stool of mixed consistency were included in another factor, which was inversely correlated with CTT. This phenomenon, called the morning rush syndrome, apparently depends on a short transit time in the rectosigmoid [14]. Abdominal pain was significantly correlated to the left faecal loading. The only physical sign that significantly correlated with CTT and faecal loading was a palpable mass (faeces) in the left fossa.

Manometric studies showed that a higher CTT was correlated with a greater volume of first sensation.

In the present study, the intake of patients with a broad spectrum of abdominal and anorectal symptoms allowed us to identify a subgroup of 90 patients with a mean CTT equal to, or less than, the CTT of the controls. In all colon segments, these patients had significantly increased faecal loadings compared to the controls, that is, constipation with a normal transit, called hidden constipation. Thus, the X-ray markers and faecal load were not correlated, apparently indicating a mismatch between the transport of markers and the propulsion of faeces at this lower level of CTT. In severe cases, no differences in colonic faecal loading were then observed between patients with a few or many markers in the colon (Figure 2). The data suggest that an increased faecal load in the colon, even with a normal CTT, can cause bloating and pain, and induce different modes of defecation. Also, this subgroup of patients had a significant higher mean age than the controls, indicating that functional faecal retention seems related to increasing age.

To date, colonic length has not been considered as a significant factor in constipation [16]. However, CTT increases with the number of colonic redundancies (colon length), which aggravated bloating, abdominal pain, and infrequent defecations. This correlation is in line with the older studies, in which a redundant colon was associated with marked constipation, pain and gas [6, 9]. The incidence of a redundant colon is low [6, 9], but higher percentages have been found in studies of colonic adenomas [17].

The present study was interventional for studying the ehtiology of faecal retention and is primarily not a therapeutic trial. Rather, patients received an established bowel stimulatory treatment. High dietary fibre intake is associated with rapid transit time [18]. Cisapride increases bowel transit in patients with chronic constipation [19], and in patients with constipation-dominant irritable bowel [20]. After cisapride was withdrawn from the market, domperidone was prescribed instead [21]. After intervention, CTT and faecal loading were significantly reduced, except in the subgroup of 90 patients who had an initial CTT similar to controls. Bloating and abdominal pain were significantly reduced, and the ease of defecation improved with solid faeces, and significant reductions in repetitiveness and incompleteness. These improvements also occurred in the subgroup with a normal CTT, but with heavier faecal loading than the controls. Analyses of the elimination rates of markers showed that patients with faster elimination rates were more likely to benefit from the intervention with cessation of pain and bloating. A recent prokinetic drug, tegaserod, significantly accelerates CTT and relieves bowel symptoms as well [22].

Functional bowel disorders have long been identified by symptom-based approaches as the Rome criteria [23]. The present data suggest that constipation and/or diarrhoea seems to be different manifestations of the same underlying condition, that is, a build-up of faecal retention reservoirs (functional faecal retention) which can only be detected by analyzing abdominal radiographs for CTT and faecal distribution. This suggests that defecation patterns do not reflect the amount of faeces in the colon. Apparently, colon function is inhibited in daily life as shown by the significant decrease in high amplitude propagated contractions in patients with slow transit constipation and constipation-dominant irritable bowel syndrome, compared to controls [24].

In the present study, patients reported a significant improvement in quality of life, including a better general condition without episodes of fever. A toxic substance has been denied to promote so-called autointoxication or constipation fever [16]. However, flu-like extra intestinal symptoms may occur with altered bowel habits and the condition may be relieved, as here, by a prokinetic agent [25].

In this study a rather high proportion of the patients had gallstones, which formation is related to slow colonic transit or an indolent intestine [26]. A constipated colon increases the risk of developing diverticula, polyps, and malignancy [27, 28]. Epidemiological data has shown that diverticular disease and adenomatous polyps are unknown, and colon cancer exceedingly rare in non-western communities that are exempt from appendicitis [29]. This evidence points towards a "common cause" behind these diseases [29] and faecal retention reservoirs in the colon could be a unifying factor underlying these diseases. The patients in this study who had previous appendectomies had a significantly longer CTT compared to patients who had not. Appendicitis caused by an obstructing fecolith might then be the first sign of faecal accumulation in the right

colon [7], just as appendicitis has also been shown to occur antecedent to increased incidence of cancer in the colon and rectum [30]. Strikingly, familial colorectal cancer occurred significantly more often in our patients who had a higher mean faecal load than the controls. Thus, patients, who have faecal retention but a normal CTT, may run a cumulative risk that this primary functional disease could lead to organic colorectal diseases.

In summary, patients with bowel symptoms exhibit significant correlations of abdominal and anorectal symptoms with CTT and faecal loading. Further, CTT increased significantly with the number of colonic redundancies (colon length) as did the abdominal pain, bloating and infrequent defecation. A subgroup of patients presented with normal CTT, but with a heavy faecal load of the colon (hidden constipation). Familial colorectal cancer occurred significantly more often in patients who had higher mean faecal load than the controls. The present work may lead to a revised diagnostic approach towards patients with a variety of abdominal and rectoanal symptoms by providing a measurable physiologic marker, the combined assessment of colon transit time, faecal loading, and colon length (redundancies). The effectiveness of a prokinetic regimen verified the pre-existing faecal overload in the colon, induced propulsion of faeces, and reduced abdominal pain, bloating, and defecation disorders. It remains to be shown in a controlled trial that patients with a normal CTT, but with faecal retention could benefit of a prokinetic regimen.

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References

1. Kumar D, Bartolo DCC, Devroede G et al. Symposium on constipation. Int J Colorectal Dis 1992;7:47-67.
2. Dawson AM. Origin of pain in the irritable bowel syndrome. In: Read NW. Irritable bowel syndrome. London: Grune & Stratton, Inc., 1985:155-62.
3. Raahave D, Loud FB. Additional faecal reservoirs or hidden constipation: a link between functional and organic bowel disease. Dan Med Bull 2004;51:422-5.
4. Bouchoucha M, Devroede G, Arhan P et al. What is the meaning of colorectal transit time measurement? Dis Colon Rectum 1992;35:773-82.
5. Leech SC, McHugh K, Sullivan PB. Evaluation of a method of assessing faecal loading on plain abdominal radiographs in children. Pediatr Radiol 1999;29:255-8.
6. Brumer P, Seppala P, Wegelius U. Redundant colon as a cause of constipation. Gut 1962;3:140-1.
7. Raahave D, Christensen E, Moeller H et al. Origin of acute appendicitis: Fecal retention in colonic reservoirs: a case control study. Surg Infect 2007;8:55-61.
8. Devroede G, Bouchoucha M, Steiber W. A simplified way to assess colorectal transit time. Tech Coloproctol 1999;3:71-3.
9. Kantor JL. Common anomalies of duodenum and colon: their practical significance. JAMA 1931;97:1785-90.
10. Caffey J. Pediatric X-ray diagnosis. The large intestine. 4. ed. Chicago: Year Book Medical Publishers Inc., 1961:613-46.
11. Jorge JMN, Wexner SD. A practical guide to basic anorectal physiology investigation. Contemp Surg 1993;43:214-24.
12. Meineche-Schmidt V, Christensen E. Classification of dyspepsia. Identification of independent symptom components in 7270 consecutive, unselected dyspepsia patients from general practice. Scand J Gastroenterol 1998; 33: 1262-72.
13. Armitage P, Berry G. Statistical method in medical research. Oxford: Blackwell, 1994.
14. Bouchoucha M, Devroede G, Dorval E et al. Different segmental transit times in patients with irritable bowel syndrome and “normal” colonic transit time:is there a correlation with symptoms? Tech Coloproctol 2006;10:287-96.
15. Halder SLS, Locke III GR, Schleck CD et al. Natural history of functional gastrointestinal disorders: A 12-year longitudinal population-based study. Gastroenterology 2007;133:799-807.
16. Mueller-Lissner SA, Kamm MA, Scarpignato C et al. Myths and misconceptions about chronic constipation. Am J Gastroenterol 2005;100:232-42.
17. Winawer SJ, Stewart ET, Zauber AG et al. Comparison of colonoscopy and double-contrast barium enema for surveillance after polypectomy. N Engl J Med 2000;342:1766-72.
18. Prior A, Whorwell PJ. Double blind study of ispaghula in irritable bowel syndrome. Gut 1987;28:1510-3.
19. Mueller-Lissner SA, Bavarian Constipation Study Group. Cisapride in chronic idiopathic constipation: can the colon be re-educated. Europ J Gastroenterol Hepatol 1995;7:69-73.
20. Van Outryve M, Milo R, Toussaint J et al. “Prokinetic” treatment of constipation-predominant irritable bowel syndrome: a placebo-controlled study of cisapride. J Clin Gastroenterol 1991;13:49-57.
21. Milo R. Use of peripheral dopamine antagonist, domperidone, in the management of gastro-intestinal symptoms in patients with irritable bowel syndrome. Curr Med Res Opin 1980;6:577-84.
22. Evans BW, Clark WK, Moore DJ et al. Tegaserod for the treatment of irritable bowel syndrome and chronic constipation. Cochrane Database of Systematic Reviews 2007, Issue 4. Art. No.:CD003960.
23. Longstreth GF, Thompson WG, Chey WD et al. Functional bowel disorders. Gastroenterology 2006;130:1480-91.
24. Bassotti G, Christolini F, Marinozzi G et al. Abnormal colonic propagated activity in patients with slow transit constipation and constipation-predominant irritable bowel syndrome. Digestion 2003;68:178-83.
25. Lin HC, Pimentel M. Bacterial concepts in irritable bowel syndrome. Rev Gastroenterol Disord 2005;5 (suppl) 3:S3-9.
26. Heaton KW, Emmett PM, Symes CL et al. An explanation for gallstones in normal weight women: slow intestinal transit. Lancet 1993;341:8-10.
27. Stefanson T, Ekbom A, Sparen P et al. Increased risk of left sided colon cancer in patients with diverticular disease.Gut 1993;34:499-502.
28. Watanabe T, Nakaya N, Kurashima K et al. Constipation, laxative use and risk of colorectal cancer: The Miyagi Cohort Study. 2004;40:2109-15.
29. Burkitt DP. The aethiology of appendicitis. Br J Surg 1971;58:695-9.
30. Arnbjørnsson E. Acute appendicitis as a sign of a colorectal carcinoma. J Surg Oncol 1982;20:17-20.