CLINICAL–ALIMENTARY TRACT

Relationship of Abdominal Bloating to Distention in Irritable Bowel Syndrome and Effect of Bowel Habit

LESLEY A. HOUGHTON,* RICHARD LEA,* ANVRAG AGRAWAL,* BRIAN REILLY,‡ and PETER J. WHORWELL*
*Neurogastroenterology Unit and ‡Department of Clinical Engineering, Academic Division of Medicine and Surgery, Wythenshawe Hospital, Manchester, United Kingdom

See editorial on page 1337.

Background & Aims: The relationship between the sensation of bloating, often ranked as the most bothersome symptom by patients with irritable bowel syndrome (IBS), and actual distention manifest as an increase in abdominal girth is controversial. Investigation of this problem has been hampered by the lack of a reliable ambulatory technique to measure abdominal girth. The aim of this study was to use the technique of abdominal inductance plethysmography to compare diurnal variation in girth in IBS patients and healthy volunteers, relating these changes to the sensation of bloating. **Methods:** Abdominal girth was recorded for 24 hours in 20 IBS-constipation (age, 18–73 y), 20 IBS-diarrhea (age, 25–62 y) and 10 IBS-alternating (age, 21–59 y) female patients meeting Rome II criteria and 20 healthy female controls (age, 18–67 y). All subjects pursued normal daily activities, recording their symptoms of bloating and pain together with bowel habit. **Results:** All patients with IBS, irrespective of bowel habit, reported significantly greater bloating than controls ($P < .0001$). Forty-eight percent of patients also showed distention beyond the 90% control range, with this being most prominent in IBS-constipation. Bloating correlated strongly only with distention in IBS-constipation ($r \geq 0.48$; $P \leq .02$). Neither bloating nor distention in IBS was related to body mass index, age, parity, or psychologic status. **Conclusions:** Abdominal distention is a clearly definable phenomenon in IBS that can reach 12 cm. However, it only occurs in half of patients reporting bloating, and the 2 only correlate in IBS-constipation. Bloating and tentiodisn may differ pathophysiologically and this appears to be reflected in the bowel habit subtype.

Bloating is reported by up to 96% of patients with irritable bowel syndrome (IBS),[1–6] is more common in females,[7,8] and is often ranked as their most bothersome symptom.[3,9] Sufferers typically report a worsening of bloating as the day progresses, particularly after meals, with a tendency for the symptom to improve or disappear overnight.[5,10] Bloating appears to be more common in patients with constipation (IBS-C) than diarrhea-predominant IBS (IBS-D),[3–5,8] although this has not been confirmed in all studies.[11] Bloating also is reported by 10%–30% of the general population,[12–15] with a recent study suggesting that of the individuals who experience bloating, 65% complain that it is moderate to severe, 54% report some associated reduction in daily activities, 43% had taken medication for their bloating, and 16% had sought medical advice.[15] Healthy women are twice as likely to report bloating than men, with this excess being unrelated to menstruation.

The subjective sensation of bloating often is viewed as being synonymous with actual abdominal distention or an increase in girth. However, a recent questionnaire study has suggested that a quarter of IBS patients believe their bloating is not associated with abdominal distention.[5] Of the IBS patients who reported bloating with abdominal distention, constipation was more common, whereas bloating alone was more common in those with IBS-D.[5] Bloating with distention also appeared to be more prevalent in female than male patients,[5] although bloating alone was reported to be either of similar[5] or reduced[4] prevalence in female compared with male IBS patients.

Attempts to quantify abdominal distention using a tape measure have suggested that girth is greater at the end of the day compared with the beginning of the day in IBS patients, with this change exceeding what is sometimes seen in healthy volunteers.[16,17] However, neither of these studies attempted to correlate the subjective sensation of bloating with abdominal distention or examined the influence of predominant bowel habit. Moreover, the use of a tape measure may be open to bias by either the patient and/or investigator, especially if it is necessary to record girth over prolonged periods of time. For example, the patient, in an attempt to show the severity of his or her problem, could voluntarily protrude his or her abdomen during a single measurement, or the investigator inadvertently could influence measurements by application of the tape measure in slightly different positions on the abdomen, or with varying degrees of tightness, particularly if they are performed at different times of the day. To overcome these problems, we recently developed and validated a technique called *abdominal inductance plethysmography*, which allows accurate, objective, ambulatory measurement of abdominal girth over 24 hours or more.[18,19] By using this technique, the aim of this study was to examine the relationship between the subjective sensation of

Abbreviations used in this paper: CI, confidence interval; IBS-alt, irritable bowel syndrome with alternating bowel habits; IBS-C, irritable bowel syndrome with constipation; IBS-D, irritable bowel syndrome with diarrhea.

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bloating and true physical abdominal distention in female IBS patients with either diarrhea, constipation, or an alternating bowel habit, and to compare any changes seen with those observed in healthy women.

Materials and Methods

Subjects

Fifty female patients who fulfilled Rome II criteria for IBS[20] and specifically complained of bloating as part of their symptom complex were recruited from the outpatient department of the South Manchester University Hospital, of whom 20 had IBS-D (age, 25–62 y; mean, 38.1 y), 20 had IBS-C (age, 18–73 y; mean, 44.2 y), and 10 had an alternating bowel habit (IBS-alt) (age, 21–59 y; mean, 36.2 y). All patients underwent appropriate investigations to exclude organic disease[21] and did not show any functional disorder of the upper gastrointestinal tract that was more prominent than their IBS. In addition, 20 healthy female volunteers (age, 18–67 y; mean, 41.2 y) were recruited into the study. All subjects drank less than the recommended safe alcohol limit (women, <14 U/wk; men, <21 U/wk) and were not taking drugs that might modify gastrointestinal function. The study was approved by the South Manchester Local Research Ethics Committee, and all subjects gave written informed consent.

Abdominal Inductance Plethysmography

The technique we used in this study has been described in detail elsewhere[18,19] but, briefly, it works on the principle that a loop of wire forms an inductor, the inductance of which is dependent on the area enclosed by the loop. For the purposes of abdominal inductance plethysmography, the wire is sewn into a band of elastic fabric (≈8.5-cm wide) in a zigzag fashion to allow for expansion (Respitrace inductive sensor; Ambulatory Monitoring Inc., New York, NY) and is worn around the abdomen, similar to a belt. Attached to the wire is a small electronic circuit unit that incorporates an inductor in a resonant circuit whose output frequency varies with the area enclosed by the band, and a small battery-operated microprocessor data logger that records and stores the average frequency of the oscillator circuit for 30 seconds each minute. The data logger simultaneously records the subject's posture (standing, sitting, and lying down) via sealed mercury tilt switches (ASSEMtech Europe Ltd., Essex, UK) taped to the subject's chest and thigh. The cross-sectional area of the abdomen recorded by the equipment then is converted into a circumferential measurement, as described previously.[18,19]

Protocol

After an overnight fast, all subjects arrived at the Neurogastroenterology Unit before 10 AM and were fitted with the abdominal inductance plethysmography device. Each subject completed a Hospital Anxiety and Depression Questionnaire[22] and was given a paper diary on which to record, at hourly intervals, the following parameters: severity of any abdominal bloating and pain/discomfort using a 0–5 scale (0 = none, 1 = very mild, 2 = mild, 3 = moderate, 4 = severe, and 5 = very severe), the time and consistency of any bowel movement (1 = watery stool, 2 = loose stool, 3 = somewhat loose stool, 4 = neither loose or hard stool, 5 = somewhat hard stool, 6 = hard stool, 7 = very hard stool), and the time and content of any oral intake (both solids and liquids). The subjects then were allowed to leave the laboratory and were asked to maintain their usual daily activities until they returned for removal of the equipment 24 hours later, at which time they were asked to give an overall retrospective assessment of the severity of their bloating and pain/discomfort for the whole 24-hour study period as either none, mild, moderate, or severe (score, 0–3).

Data Analysis

The subjective diary bloating scores for the hour at the start of the study and before retiring to bed on day 1, and on waking on day 2 were used to evaluate any diurnal variation in bloating. In addition, the mean bloating score between the beginning and end of day 1 referenced to the beginning of day 1 (ie, mean bloating score from second hour of the study to the end of day 1 − the mean bloating score for first hour of the study) and the patients overall retrospective symptom scores were compared between subject groups.

Because previous studies have shown that there is no statistically significant difference between girth measurements taken in the standing and sitting positions,[18] girth whether in the sitting or standing position was averaged over 30-minute epochs at the following times: (1) at the beginning of the study on day 1, (2) before retiring to bed on day 1, and (3) immediately after waking on day 2. Data obtained in the lying-down posture were averaged for the 30 minutes immediately after going to bed on day 1 and again before rising on day 2. Maximum distention was defined as the mean girth over 30 minutes of recording at which point girth was at its greatest. Whether maximal girth was associated with the end of day, meal ingestion, or no specific identifiable event was noted. In addition, the mean abdominal girth from the beginning to end of day 1 referenced to the beginning of day 1 (ie, mean abdominal girth from the second hour of the study to the end of day 1 − the mean girth for the first hour of the study) was determined. Changes in abdominal girth and subjective bloating scores between subject groups were compared using independent *t* tests. Correlations between mean values and changes in abdominal girth and subjective bloating scores, together with correlations between overall retrospective bloating scores and either bloating score at the end of the day, pain/discomfort or anxiety, and change in girth with anxiety were performed using the Pearson test. Overall within-subject correlations using hourly data also were derived.

Results

Demographic Characteristics

The demographic and baseline characteristics of participants are summarized in Table 1. Analyses for homogeneity showed no relevant differences in these between-subject groups.

The Symptom of Abdominal Bloating

IBS patients vs healthy volunteers. IBS patients reported significantly more bloating both at the beginning and the end of day 1, and on waking on day 2 compared with healthy volunteers ($P < .0001$) (Figure 1). In addition, the IBS patients, but not the healthy volunteers, reported more severe bloating at the end of day 1 compared with both the beginning of day 1, and on waking on day 2 ($P < .001$) (Figure 1). This increase in bloating from the beginning to end of day 1 (mean,

Table 1. Subject Characteristics

	HV (n = 20)	IBS-D (n = 20)	IBS-C (n = 20)	IBS-alt (n = 10)
Age, *y*	42.3 (35.4–49.2)	43.2 (37.1–49.2)	38.1 (31.7–44.6)	36.2 (25.8–46.6)
Body mass index, *kg/m²*	25.5 (23.2–27.8)	24.4 (21.8–27.0)	24.8 (22.7–27.0)	25.3 (21.7–29.0)
Baseline girth, *cm*	85.4 (78.7–92.1)	87.1 (78.2–96.1)	83.7 (77.1–90.2)	79.2 (70.9–87.5)
Parity	1.3 (0.8–1.9)	1.3 (0.6–2.0)	0.8 (0.3–1.4)	0.7 (0.0–1.4)

NOTE. Data are expressed as mean (95% CI).
HV, healthy volunteers.

1.17; 95% confidence interval [CI], 0.73–1.61) and its subsequent decrease from the end of day 1 to waking on day 2 (mean, −0.88; 95% CI, −0.44 to −1.32) was significantly greater than that seen in the healthy volunteers (mean, 0.2; 95% CI, −0.1 to 0.5; $P = .001$; and mean, −0.12; 95% CI, −0.54 to 0.32; $P = .02$, respectively).

Likewise, the mean bloating score from the beginning to end of day 1 referenced to the beginning of the day 1 (mean, 0.78; 95% CI, 0.45–1.18) and retrospective overall bloating severity score (mean, 2.1; 95% CI, 1.8–2.3) were higher in the IBS patients compared with the healthy volunteers (mean, 0.09; 95% CI, 0–0.29; $P = .001$; and mean, 0.35; 95% CI, 0.1–0.6; $P < .001$, respectively).

All IBS patients and 7 of the healthy volunteers reported bloating on the day of the study.

Effect of bowel habit. All IBS patients, whether they had diarrhea, constipation, or an alternating bowel habit, had more severe bloating at the beginning and end of day 1 and on waking on day 2 compared with healthy volunteers ($P < .0001$) (Figure 1). All 3 IBS subgroups also reported more severe bloating at the end of day 1 compared with both the beginning of day 1 and on waking on day 2 ($.0001 \leq P \leq .08$) (Figure 1), such that the increase in bloating from the beginning to end of day 1 (IBS-D: mean, 1.47; 95% CI, 0.87–2.07; $P = .001$; IBS-C: mean, 0.84; (95% CI, 0.08–1.6; $P = .03$; IBS-alt: mean, 1.2; 95% CI, 0.13–2.28; $P = .10$ compared with healthy volunteers) and the reduction in bloating from the end of day 1 to waking on day 2 (IBS-D: mean, −0.70; 95% CI, −1.44 to 0.04; $P = .19$; IBS-C: mean, −0.92; 95% CI, −1.64 to −0.2; $P = .06$; IBS-alt: mean, −1.33; 95% CI, −1.99 to 0.67; $P = .009$ compared with healthy volunteers) was greater than that seen in the healthy volunteers. There was no statistically significant difference in any of these changes in severity of bloating between the IBS subgroups. Comparison of bloating severity between the IBS subgroups at each individual time period revealed no statistically significant differences, except for IBS-D patients who had lower scores at the beginning of day 1 than reported by the IBS-C patients ($P = .05$) (Figure 1).

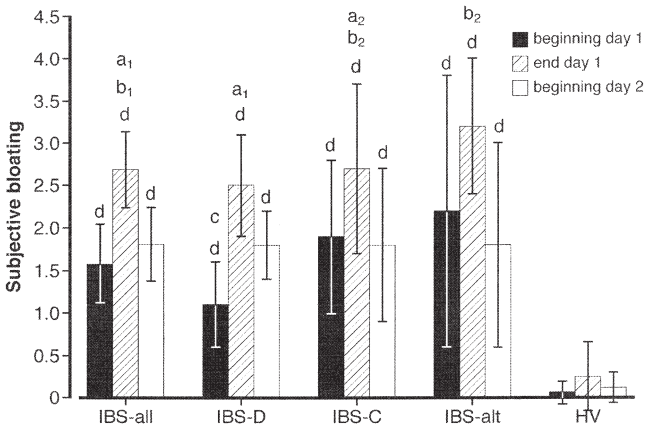

Figure 1. Comparison of subjective score of abdominal bloating at the beginning and end of day 1 and at the beginning of day 2 in IBS patients overall (IBS-ALL), IBS-D, IBS-C, IBS-alt, and healthy volunteers (HV). Data are expressed as mean and 95% confidence intervals. a_1: $P < .0001$, a_2: $P < .05$, compared with the beginning of day 1; b_1: $P < .0001$, b_2: $P < .05$ compared with the beginning of day 2; c: $P = .05$ compared with IBS-C; d: $P < .0001$ compared with the corresponding time period for HV.

The mean bloating score from the beginning to the end of day 1, referenced to the beginning of day 1, was similarly greater in patients with IBS-D (mean, 1.06; 95% CI, 0.66–1.46) and IBS-alt (mean, 0.84; 95% CI, 0.10–1.58), but not IBS-C (mean, 0.38; 95% CI, 0.06–0.70) compared with healthy volunteers (mean, 0.09; 95% CI, 0–0.29; $P < .005$). There was no difference in this parameter between IBS-D and IBS-alt patients. Likewise, there was no difference in overall retrospective bloating severity scores between the IBS subgroups (IBS-D: mean, 2.0; 95% CI, 1.7–2.4; IBS-C: mean, 2.2; 95% CI, 1.8–2.6; IBS-alt: mean, 1.9; 95% CI, 1.4–2.3; $P > .3$). Last, division of the IBS patients into those who did or did not have bowel movements during the 24-hour study period showed that those who did have at least one bowel movement reported a similar overall retrospective bloating score to those who did not (patients having bowel movements [n = 39]: mean, 2.1; 95% CI, 1.8–2.3 vs patients not having bowel movements [n = 9]: mean, 2.0; 95% CI, 1.5–2.5 [diary data was missing for 2 patients]).

Actual Changes in Abdominal Girth (Distention)

IBS patients vs healthy volunteers. There was no difference in abdominal girth at the beginning of day 1 between the IBS patients and healthy volunteers (Table 1, Figure 2). IBS patients' girth, however, was significantly greater at the end of day 1 compared with both the beginning of day 1 and on waking on day 2 ($P < .001$), and slightly lower on waking on day 2 compared with the beginning of day 1 ($P = .11$) (Figure 2). In contrast, in healthy volunteers, girth did not significantly change from the beginning to end of day 1 ($P = .86$), although girth on waking on day 2 was slightly lower than at the beginning ($P = .12$) and end ($P = .09$) of day 1. Comparison of the changes in girth from the beginning to end of day 1 and from the end of day 1 to waking on day 2 showed that they were both significantly greater in the IBS patients compared with the healthy volunteers (mean, 2.99 cm; 95% CI, 1.39–4.39 cm vs mean, −.23 cm; 95% CI, −2.35 to 1.89 cm; $P = .03$; and mean, −4.45 cm; 95% CI, −5.73 to −3.17 cm vs mean, −1.21 cm; 95% CI, −2.57 to 0.15 cm; $P = .02$, respectively).

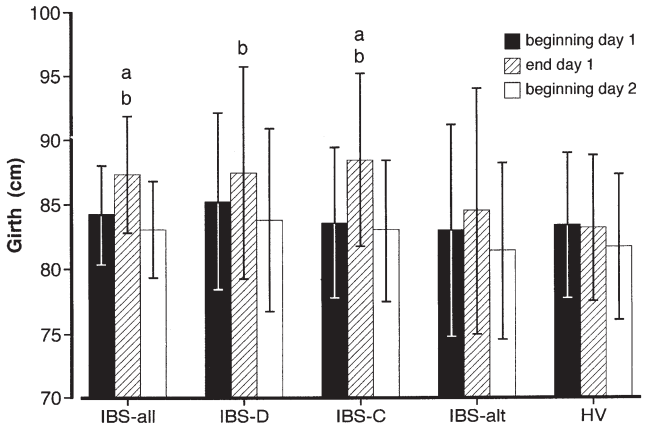

Figure 2. Comparison of abdominal girth at the beginning and end of day 1 and beginning of day 2 in IBS patients overall (IBS-all), IBS patients with diarrhea (IBS-D), IBS patients with constipation (IBS-C), IBS patients with an alternating bowel habit (IBS-alt), and healthy volunteers (HV). Data are expressed as mean and 95% confidence interval. a: $P \leq .001$ compared with the beginning of day 1; b: $P \leq .001$ compared with the beginning of day 2.

Likewise, the mean abdominal girth from the beginning to the end of day 1 referenced to the beginning of day 1 was significantly greater for IBS patients compared with the healthy volunteers (mean, 2.16 cm; 95% CI, 1.06–2.22 cm vs mean, −0.1 cm; 95% CI, −0.88 to 0.68 cm; $P < .01$).

Supine girth measured immediately before rising from bed on day 2 was significantly lower than girth assessed immediately after retiring to bed on day 1 in both patients with IBS and healthy volunteers ($P < .001$) (Figure 3).

Interestingly, in only 46% of IBS patients was maximal girth at the end of the day, with 24% exhibiting maximal girth at the time of meal ingestion, and 30% in relation to no specific identifiable event (Table 2).

The mean abdominal girth from the beginning to the end of day 1, referenced to the beginning of day 1 for each individual IBS patient, compared with the 90% reference range obtained from the healthy volunteers showed that 48% of patients distended beyond the 95th percentile for healthy volunteers.

Effect of bowel habit. Abdominal girth at the beginning of day 1 was no different in the IBS-C, IBS-D, or IBS-alt patients compared with the healthy volunteers (Table 1, Figure 2). In patients with IBS-C, girth was significantly greater at the end of day 1 compared with both the beginning of day 1 and on waking on day 2 ($P < .001$), such that the increase in girth from the beginning to end of day 1 (mean, 4.57 cm; 95% CI, 2.47–6.67 cm vs mean, −0.23 cm; 95% CI, −2.35 to 1.89 cm) and the decrease in girth from the end of day 1 to waking on day 2 (mean, −5.82 cm; 95% CI, −7.72 to −3.92 cm vs mean, −1.21 cm; 95% CI, −2.57 to 0.15 cm) were both greater than seen in healthy volunteers ($P = .004$). In IBS-D patients, similar changes were seen but did not reach statistical significance (mean, 2.65 cm; 95% CI, −0.23 to 5.53 cm; $P = .19$ and mean, −3.78 cm; 95% CI, −5.54 to −2.02 cm; $P = .08$ compared with healthy volunteers, respectively) (Figure 2), whereas in the IBS-alt patients there was only a tendency for girth from the end of day 1 to waking on day 2 to decrease (mean, 0.49 cm; 95% CI, −3.11 to 3.59 cm; P = NS and mean, −3.08 cm; 95% CI, −6.82 to 0.66 cm; $P = .14$ compared with healthy volunteers) (Figure 2). Similarly, the mean girth from the beginning to end of day 1 referenced to the beginning of day 1 was greater in all 3 IBS subgroups compared with healthy volunteers (IBS-D: mean, 2.45 cm; 95% CI, 0.73–4.17 cm and IBS-C: mean, 2.42 cm; 95% CI, 1.52–3.32 cm; both $P \leq .01$; and IBS-alt: mean, 1.16 cm; 95% CI, −.26 to 2.58 cm; $P = .12$ compared with healthy volunteers), although slightly lower in IBS-alt patients compared with IBS-C patients ($P = .17$).

Supine girth was significantly reduced in all 3 IBS subgroups, as measured immediately after retiring to bed on day 1 to immediately before rising from bed on day 2 ($P \leq .02$) (Figure 3), although only in the IBS-C patients was this change greater than that seen in the healthy volunteers (IBS-C: mean, −3.82 cm; 95% CI, −5.35 to −2.3 cm; $P = .04$; IBS-D: mean, −2.90 cm; 95% CI, −4.24 to −1.54 cm; P = NS; IBS-alt: mean, −2.18 cm; 95% CI, −3.64 to −0.72 cm; P = NS; compared with healthy volunteers: mean, −1.89 cm; 95% CI, −2.83 to −0.95 cm). There was no difference in change in supine girth between IBS subgroups.

With respect to the time of maximal girth, most patients with IBS-C showed maximal girth at the end of day 1 (65%), whereas patients with IBS-D and IBS-alt typically showed maximal girth either in relation to a meal or no identifiable specific event (IBS-D, 65%; IBS-alt, 70%) (Figures 4*A* and *B*) (Table 2).

Division of the patients into those who did and did not have a bowel movement during the 24-hour study period showed that those patients who did not have a bowel movement had a tendency to show greater changes in abdominal girth from the beginning to end of day 1 (mean, 5.72 cm; 95% CI, 1.23–10.21 cm) than those who did have a bowel movement (mean, 2.25 cm; 95% CI, 0.49–4.0 cm; $P = .09$).

Comparison with the 90% reference range for mean girth from the beginning to end of day 1 referenced to girth at the beginning of day 1 for healthy volunteers showed more patients with IBS-C (60%) distended compared with both IBS-D (40%) and IBS-alt (40%) ($P = .036$).

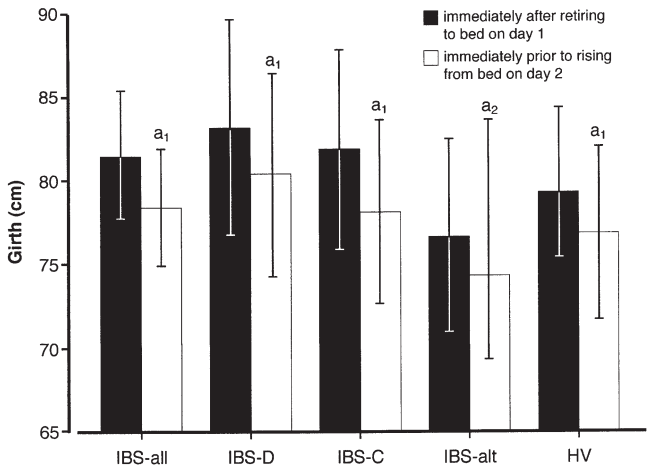

Figure 3. Comparison of supine girth immediately after retiring to bed on day 1 and immediately before rising from bed on day 2 in IBS patients overall (IBS-ALL), IBS-D, IBS-C, IBS-alt, and healthy volunteers (HV). Data are expressed as mean and 95% confidence interval. a_1: $P < .001$; a_2: $P = .02$ compared with immediately after retiring to bed on day 1.

Table 2. Descriptive Characteristics of Maximal Abdominal Girth in IBS and Healthy Subjects

	HV (n = 20)	All IBS subgroups (n = 50)	IBS-D (n = 20)	IBS-C (n = 20)	IBS-alt (n = 10)
Maximum change in abdominal girth from beginning of day 1, *cm*	5.1 (3.3–6.9)	7.4 (6.2–8.7)[a]	7.6 (5.8–9.6)[a]	8.3 (5.9–10.7)[a]	5.2 (3.4–7.0)
Timing of maximum girth					
End of day	7 (35%)	23 (46%)	7 (35%)	13 (65%)	3 (30%)
Meal	6 (30%)	12 (24%)	8 (40%)	2 (10%)	2 (20%)
No specific event	7 (35%)	15 (30%)	5 (25%)	5 (25%)	5 (50%)

NOTE. Data are expressed as mean (95% CI). Numbers in parantheses represent percentage of total number of subjects in each group.
HV, healthy volunteers.
[a]$P \leq .05$ compared with healthy volunteers.

Relationship of Bloating and Abdominal Distention

The retrospective overall bloating score showed a strong correlation with the following: (1) the bloating score obtained before bed on day 1 ($r = 0.62$; $P < .0001$), (2) the mean bloating score from the beginning to end of day 1 ($r = 0.63$; $P < .01$), and (3) the maximal bloating score during day 1 ($r = 0.73$; $P < .01$). The change in girth from the beginning to end of day 1 directly correlated with both the severity of bloating at the end of day 1 ($r = 0.28$; $P = .06$) and patients' overall retrospective assessment of their bloating ($r = 0.31$; $P = .03$). Likewise, there was a direct within-subject correlation between bloating and distention when using hourly data ($r = 0.32$; $P < .001$).

With regard to the IBS patient subgroups, only the IBS-C, but not the IBS-D or IBS-alt patients, showed a strong correlation between bloating and distention when comparing the change in girth from the beginning to end of day 1 with bloating before bed ($r = 0.6$; $P = .01$) or the retrospective overall bloating score ($r = 0.5$; $P = .02$). However, both IBS-C and IBS-D showed a direct within-subject correlation between bloating and distention when comparing the hourly data (IBS-C: $r = 0.48$, $P < .0001$; IBS-D: $r = 0.28$, $P < .0001$; IBS-alt: $r = 0.12$, NS) (Figure 4*A* and *B*), although many more individual patients with IBS-C showed a correlation with an r of 0.5 or more (72%) than either patients with IBS-D (30%) or IBS-alt (22%) (Table 3). Furthermore, the retrospective overall bloating score strongly correlated with abdominal pain/discomfort ($r = 0.71$; $P < .0001$).

Relationship of Anxiety, Age, Body Mass Index, and Parity to Bloating and Distention

No relationship was found between either bloating or distention with patient anxiety, age, body mass index, baseline girth, or parity.

Discussion

This study objectively measured abdominal girth in IBS patients over a 24-hour period and assessed the relationship between bloating, distention, and bowel habit. It confirms that abdominal distention is a real phenomenon in IBS patients, with a proportion of patients showing a substantial increase in girth over the course of a day, which can reach up to 12 cm. Only in patients with IBS-C, however, was there a strong direct correlation between the symptom of bloating and distention.

The mechanisms underlying bloating and distention in IBS are poorly understood, but our observation that bloating only strongly correlates with distention in patients with constipation suggests that the pathophysiology is likely to be multifactorial and may well differ between the 3 bowel-habit subgroups. In the past, the bloating and distention reported by IBS patients has been regarded with great skepticism, with the suggestion that it is a psychologic symptom resulting from the deliberate protrusion of the abdomen.[23] However, our results refute this proposition and also have shown that there appears to be no relationship between bloating or distention and the psychologic status of the patient. This is in agreement with previous questionnaire studies that also were unable to identify any relationship with psychologic factors.[3–5,8,9] Moreover, computerized tomography of the abdomen in distended IBS patients has shown that this is not caused by voluntary protrusion of the abdomen or exaggerated lumbar lordosis.[16] In addition, there was no correlation between either bloating or distention and age, body mass index, baseline girth, or parity, all of which might be expected to be associated with weakened abdominal musculature, which has been suggested previously as contributing to abdominal distention.[17] Electromyographic assessment of the anterior abdominal musculature in distended and healthy subjects does not appear to reveal any differences.[24] However, if patients with distention are subjected to a rectal gas challenge, paradoxic relaxation of the internal oblique is observed compared with the increase seen in healthy subjects.[25] This suggests that there may well be some form of abdominal accommodation reflex that may be exaggerated or disturbed in patients with IBS and explain how abdominal musculature may be involved in distention, irrespective of its strength.

It would seem reasonable to assume that the accumulation of gas within the intestine might contribute to the phenomenon of distention. However, there is little evidence to support this notion although gas may well be involved in the symptom of bloating.[26,27] Most studies to date have been unable to show increased volumes of intestinal gas in patients with IBS,[16,28–31] and even in the few studies that have shown increased levels of gas there was little or no correlation with symptoms.[32,33] Furthermore, as a result of gas-infusion studies, it has become apparent that intestinal gas would need to increase 10-fold before abdominal girth increased beyond 2 cm.[29,34] However, work from the Barcelona group[29,30] has produced convincing evidence that patients with IBS may handle or transport intestinal gas abnormally, which might lead to gas trapping and stimulation of gut-wall mechanoreceptors, resulting in a sensation of bloating. A similar effect could result from sequestration of fluid or bulking of solids within segments of the intestine. Hebden et al[35] recently showed that addition of bran to a

radiolabeled meal increased small-bowel transit in healthy subjects but did not further accelerate an already rapid transit in patients with IBS. This lack of affect of bran on transit in IBS patients was associated with an exacerbation of pain and bloating, leading the investigators to conclude that it was caused by an increased bulking effect in the proximal colon. A generalized retention of fluid leading to distention is unlikely because it has been shown that large volumes of ascites are needed before there is a noticeable change in girth.[36]

Abnormal gas, fluid, or solid handling might result from a motility disorder of the gut, although most studies to date have been unable to identify reproducible abnormalities in either small- or large-bowel motor activity under normal physiologic conditions[37,38] or during infusion of intestinal gas[39] in patients with IBS compared with healthy volunteers. However, it is conceivable that any motor dysfunction could be localized or transient, making it almost impossible to detect using standard manometry. Harder et al,[40] however, recently suggested that an increase in duodenal tone in response to jejunal gas infusion may contribute to symptom production. Obviously, motility disorders can contribute to the delayed transit seen in some patients with constipation-predominant IBS[41] and based on our observations could contribute to the greater prevalence of distention seen in this group.

There is, however, preliminary evidence to support a role for heightened visceral sensation in the manifestation of the symptom of bloating. We have some preliminary evidence that those patients who experience bloating without physically distending have lower rectal visceral sensory thresholds than patients who bloat and distend.[42] Interestingly, we also found a strong correlation between the severity of bloating and pain/discomfort, supporting the observations of Chang et al[5] that the majority of patients reporting a worsening of bloating say this usually is associated with a worsening of other abdominal symptoms. This potential interrelationship between the symptoms of bloating and pain also is supported by previous observations that there is a weak correlation ($r = 0.30–0.40$) between abdominal pain and sensory threshold.[43,44] Further studies are required in large numbers of patients with various bowel habits to determine the exact relationship between sensory threshold and bloating.

Our observation that the severity of bloating experienced by patients with different bowel habits is consistent with previous studies,[11] but because we only selected patients who specifically complained of bloating as part of their symptom complex to participate in this particular study, we were unable to make comparisons with other studies on the prevalence of bloating in these different bowel-habit subgroups. It is noteworthy that IBS-C patients generally tended to feel more bloated at the beginning of the day than IBS-D patients (Figures 4*A* and *B*), and this may explain why both the change in bloating from the beginning to end of day 1, and the mean bloating score from the beginning to end of day 1 referenced to the beginning of day 1, tended to be smaller in this subgroup than that seen in IBS-D

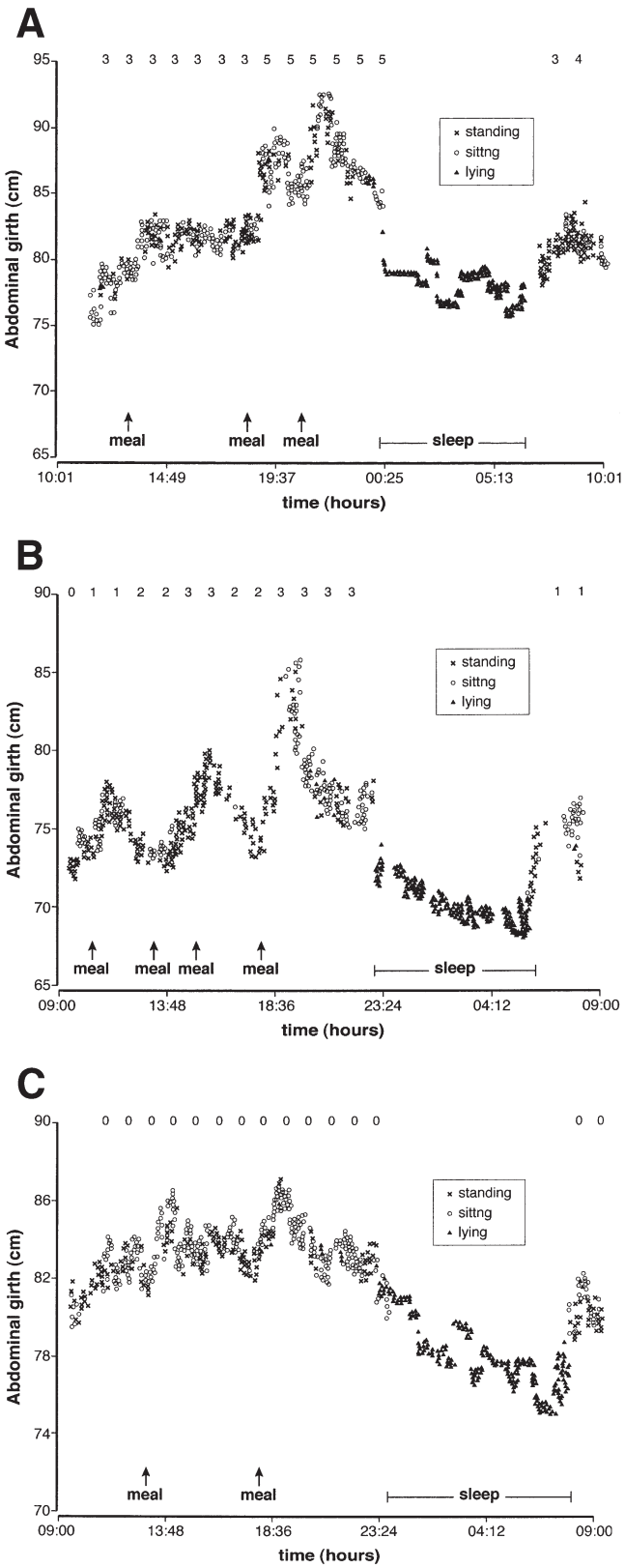

Figure 4. Typical recordings of abdominal girth over 24 hours in a patient with (*A*) IBS-C, (*B*) IBS-D, and (*C*) normal healthy volunteer. Numbers across the top of the girth recording are the bloating scores (scale, 0–5) obtained from the diary. Note the following: girth changes more both in IBS-C and IBS-D patients than in healthy volunteers, and generally relates to the sensation of bloating; IBS-C patients start the day feeling bloated whereas IBS-D patients do not; the increase in girth with meal ingestion, particularly in the IBS-D patient; and the slow reduction in girth during sleep.

Table 3. Number of Patients Showing Various Levels of Correlation Between Bloating and Abdominal Distention Using the Hourly Data Obtained During the Awake Periods of the Study

	All IBS subgroups (n = 47)	IBS-C (n = 18)	IBS-D (n = 20)	IBS-alt (n = 9)
$r \geq 0.7$	11 (23%)	6 (33%)	4 (20%)	1 (11%)
$0.7 > r \geq 0.5$	10 (21%)	7 (39%)	2 (10%)	1 (11%)
$r < 0.5$	26 (56%)	5 (28%)	14 (70%)	7 (78%)

NOTE. Three patients had incomplete bloating diary assessments. Numbers in parentheses represent percentage of total number of patients in each group.
HV, healthy volunteers.

patients. Our data, however, provide objective confirmation of previous subjective data,[5] suggesting that a greater percentage of female IBS patients with constipation distend than either female patients with IBS-D or IBS-alt. However, the percentage of patients showing distention in all 3 subgroups in our study was somewhat lower, particularly in the IBS-D (66% vs 40%) and IBS-alt (77% vs 40%) subgroups. This is probably not surprising because patients who are asked to rate distention subjectively are likely to have some difficulty in differentiating between the sensations of bloating and distention, especially because the 2 sensations do not correlate. However, the percentage of constipated patients showing distention in our study was much closer to previous subjective estimates (83% vs 60%) and this might be because distention correlates well with bloating in this subgroup. The finding that the prevalence of true distention varies between the bowel-habit subgroups and is not always related to the symptom of bloating also may help to explain the wide variation in the reporting of these 2 symptoms in IBS patients as a whole in previous studies.

Interestingly, distention was not always maximal at the end of the day, with just under half of all IBS patients (46%) showing maximal girth at the end of the day (Figure 4). The rest showed maximal girth either after ingestion of a meal (24%) (Figure 4*B*) or in relation to no specific identifiable event (30%). Maximal girth, however, tended to coincide with the end of the day much more commonly in patients with IBS-C (65%) than in patients with either IBS-D (35%) or IBS-alt (30%), whereas meal ingestion or no specific identifiable event appeared to be most likely factors associated with maximal girth (IBS-D, 65%; IBS-alt, 70%). These observations may explain in part why bloating did not correlate with the change in abdominal girth from the beginning to end of day 1 in patients with IBS-D and IBS-alt.

In our study we recruited only female subjects to obtain a more homogenous group because previous questionnaire studies have suggested a reduced prevalence and severity of distention[5] and/or bloating[4,5,8,45,46] in male compared with female IBS patients. Thus, careful characterization of the type and sex of patients being studied is essential when investigating the prevalence and pathophysiology of these 2 features of IBS. For example, a study containing greater numbers of patients with constipation than either diarrhea or an alternating bowel habit would be expected to more likely show a high prevalence of distention and correlation with the symptom of bloating. We also must be cognizant of the fact that a small percentage of IBS patients do not appear to experience bloating as part of their symptom complex, and so the data presented in this study may be somewhat different from that in the IBS population as a whole, and between patients in primary, secondary, or tertiary care.

In conclusion, our results confirm the reality of distention in IBS and identify its relationship to the symptom of bloating and to bowel-habit subtypes. Further studies examining the role of visceral sensation, transit, gas handling, and sex should help to further elucidate the nature of these puzzling features of IBS.

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Address requests for reprints to: L. A. Houghton, PhD, Senior Lecturer in Medicine and Physiological Sciences, and Manager of GI Physiological Services, Neurogastroenterology Unit, Academic Division of Medicine and Surgery, 1st Floor, F Block, Wythenshawe Hospital, Southmoor Road, Wythenshawe, Manchester, M23 9LT United Kingdom. e-mail Lesley.Houghton@manchester.ac.uk; fax: (0161) 291-4184.

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