ORIGINAL ARTICLE

Reproducibility and validity of radiographically determined gastrointestinal and segmental colonic transit times in spinal cord-injured patients

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Background: Total gastrointestinal transit times (GITT) and segmental colonic transit times (CTT) are commonly used to describe bowel function in individuals with spinal cord injury (SCI).

Study design: Reproducibility study.

Objectives: To describe inter- and intrasubjective as well as interobserver variations in GITT and segmental CTT in patients with SCI. Furthermore, to study associations between GITT or segmental CTT and colorectal symptoms.

Setting: Spinal Cord Unit, Viborg Hospital, Denmark.

Methods: Thirty SCI patients took 10 radio-opaque markers on 6 consecutive days and an abdominal X-ray was taken on day 7. The same procedure was repeated after 3 months. GITT and CTT were computed from the number of markers in the entire colorectum and in the left and the right colon. Intra- and interobserver variations were described as dispersion (numerical difference/mean).

Results: Intersubjective variation was large for GITT (range: 0.6–6.3 days), right CTT (range: 0.1–5.5 days) and left CTT (range: 0–4.9 days). Intrasubjective variation was acceptable for GITT (dispersion: 0.28) but less good for right (dispersion: 0.63) and left CTT (dispersion: 0.68). Interobserver variation was very small. No correlations were found between GITT, right or left CTT and colorectal symptoms.

Conclusion: GITT and right and left CTT are of limited value for clinical decision-making in individual patients but may be useful for comparison of groups of patients with SCI.

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Introduction

Most spinal cord-injured (SCI) patients suffer from constipation and faecal incontinence.^{1–4} Abdominal pain and other constipation-related symptoms become more severe with time since injury.^{5,6} Accordingly, total gastrointestinal transit times (GITT) and segmental colonic transit times (CTT) are prolonged in most SCI patients.^{7–10} A Cochrane review from 2006 concluded that treatment of colorectal dysfunction in patients with central neurological disease must remain empirical until large well-designed studies have been performed.¹¹ Such studies require validated symptom-based scores and valid objective end points.¹¹ Recently, a symptom-based score for neurogenic bowel dysfunction has

been developed.¹² GITT or CTT determined by means of radio-opaque markers have been extensively used for objective description of colorectal pathophysiology^{7–10} and in pharmacological studies^{13–15} among SCI patients. Furthermore, GITT and segmental CTT are included in the draft for International Spinal Cord Injury Bowel Function Extended Data Set. In healthy able-bodied patients, stool form or frequency correlate to total or left colonic transit time. Using a method with daily intake of 20 markers on 3 consecutive days followed by abdominal X-rays at days 4 and 7 among patients with SCI prolonged left and recto-sigmoid CTT were associated with a subjective feeling of unsuccessful rectal emptying.¹⁶ Also in patients with SCI, abdominal pain and faecal incontinence were more frequent in those with normal left CTT than in those in whom it was prolonged. Time required for bowel care and abdominal bloating were neither associated with total nor segmental CTT.¹⁶ Accordingly, the clinical relevance of GITT and

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segmental CTT measurements in SCI patients has been questioned.¹⁶

The aim of the present study was to evaluate reproducibility, intersubjective and interobserver variations in radiographically determined GITT and segmental CTT in SCI patients. Furthermore, we wanted to study potential correlations between GITT or segmental CTT and colorectal symptoms.

Patients and methods

Population

Patients were recruited from the outpatient clinic at the Spinal Cord Unit, Viborg Hospital. The uptake area covers the western part of Denmark (population 2.5 million). The patients had to be 18 years or older, at least 1 year post injury and having normal eating habits. Exclusion criteria were psychological instability, difficulty in communication, previous major intestinal or perianal surgery, inflammatory bowel disease, sacral nerve stimulation, use of transanal irrigation, pregnancy or lactating women.

The following background data were collected for all patients: age, gender, time since injury and cause of injury. Level and completeness of lesion were determined according to the International Standards for Classification of Spinal Cord Injury.¹⁷ Dietary habits and fluid intake were described from a 3 days diary.

The study was approved by the local Ethics Committee for the counties of Viborg and Northern Jutland, Denmark.

Colonic transit time

GITT and segmental CTT were determined by the method described by Abrahamsson *et al.*¹⁸ Patients took a capsule containing 10 ring-shaped radio-opaque markers with a diameter of 5 mm (Medifact Gotenburg, Sweden) at noon on 6 consecutive days. On day 7, a single abdominal X-ray was taken. From bony landmarks and the gaseous outline of the bowel, the colorectum was divided into the right colon (including the caecum, the ascending colon and the transverse colon until the splenic flexure) and the left colon (the splenic flexure, the descending colon and the rectosigmoid). The number of markers was counted in each segment and in the entire colorectum. Thereby, the GITT in days could be computed as

$$\text{GITT} = \{M + (f + D)\} / D$$

where *M* is the total number of markers counted from the X-ray, *D* is the number of markers taken each day and *f* is the

fraction of the daily number of markers chosen for estimation of transit. GITT is normally defined as the mean half emptying of the gut. Therefore, *f* is 0.5. If, for example, 15 markers were left on the abdominal X-ray, GITT would be {15 markers + (0.5 day × 10 markers/day)} / 10 markers/day = 2.0 days.

Segmental CTT in days were computed for the right and left colon as *N/D*, where *N* is the number of markers in the segment and *D* is the daily intake of markers (*D* = 10). If, for example, seven markers were left in the left colon, the transit time of that segment would be 7/10 = 0.7 days.

To describe the reproducibility of the results, GITT and segmental CTT were determined at inclusion and after 3 months. To assess interobserver variation, GITT and segmental CTT were determined from the X-rays by two independent observers.

Colorectal symptoms

At inclusion patients filled in a detailed 44-item questionnaire describing their colorectal function. Included in the questionnaire were all items from the neurogenic bowel dysfunction score¹² and the Cleveland Constipation score.¹⁹

Statistical analysis

Reproducibility and interobserver variations were described as dispersion computed as numerical difference/mean. Associations between GITT, left or right CTT and colorectal symptoms were evaluated with Pearson's correlation coefficient. *P* < 0.05 was considered statistically significant.

Results

Thirty patients were recruited (21 men and 9 women, age 26–68 years (mean 47)). Time since injury was 2–37 years (mean 19.5). All patients had supraconal spinal cord lesions. The neurological level of lesion was cervical in 10 patients, thoracic in 15 patients and lumbar in 5 patients. The lesion was complete in 18 patients and incomplete in 12 patients. Two patients were unavailable for follow-up after 3 months and another had a colostomy between the two investigations. Accordingly, baseline data were available for 30 patients and 27 patients had the investigation twice. Body mass index and eating and drinking habits are shown in Table 1.

Table 1 Body mass index and drinking and eating habits (data not available for all 30 patients)

Body mass index	<20 (<i>n</i> = 0)	20–25 (<i>n</i> = 13)	26–30 (<i>n</i> = 7)	31–40 (<i>n</i> = 3)	>40 (<i>n</i> = 1)
Water intake (ml per kg per day)	<10 (<i>n</i> = 0)	10–20 (<i>n</i> = 4)	21–30 (<i>n</i> = 11)	>30 (<i>n</i> = 7)	
Vegetables	Daily (<i>n</i> = 11)	At least two times per week (<i>n</i> = 12)	Never (<i>n</i> = 3)		
Fruit	Daily (<i>n</i> = 10)	At least two times per week (<i>n</i> = 9)	Never (<i>n</i> = 7)		
Number of meals per day	2 (<i>n</i> = 3)	3 (<i>n</i> = 9)	4 (<i>n</i> = 9)	5 (<i>n</i> = 4)	

Reproducibility of total gastrointestinal transit time and segmental colonic transit times

Mean GITT was 3.3 days (range: 0.6–6.3 days). Mean right colonic transit time (including the caecum, the ascending colon and the transverse colon to the splenic flexure) was

Figure 1 Difference versus mean plot for GITT determined at two occasions. Reproducibility is acceptable with dispersion (difference/mean) of 0.28 and there is no systematic error as mean difference is close to zero. GITT, total gastrointestinal transit time.

1.3 days (range 0.1–5.5) and mean left colonic transit time (including the splenic flexure, the descending colon and the rectosigmoid) was 1.8 days (range: 0–4.9).

The reproducibility test of GITT showed a dispersion (numerical difference/mean) of 0.28, for right colonic transit time it was 0.66 and for left colonic transit time it was 0.69. In seven patients (26%) variation in GITT was more than 1 day, and in three patients (11%) it was 2 days or more (Figure 1). Interobserver dispersion was 0 for GITT, 0.05 for right colonic transit time and 0.03 for left colonic transit time.

Associations between colorectal symptoms and total

gastrointestinal transit time or segmental colorectal transit times Pearson's correlation coefficient for associations among GITT, right CTT or left CTT and neurogenic bowel dysfunction score, Cleveland Constipation Score, time used per defecation, abdominal pain, difficult rectal emptying at defecation, headache/perspiration/general uneasiness during defecation, frequency of faecal incontinence or impact on quality of life because of bowel dysfunction ranged from –0.44 to 0.32 and none were statistically significant. Accordingly, neither total gastrointestinal nor left or right colorectal transit times were correlated with the Neurogenic Bowel Dysfunction Score, Cleveland Constipation Score, single constipation-related symptoms, abdominal pain, autonomous symptoms or faecal incontinence (Table 2).

Table 2 No correlation between colorectal symptoms and GITT, right CTT or left CTT

	GITT Mean (range) (days)	Right CTT Mean (range) (days)	Left CTT Mean (range) (days)
<i>Neurogenic bowel dysfunction score</i>			
0–6 (very minor dysfunction) (n = 9)	3.7 (1.5–6.3)	1.8 (0.4–3.8)	1.5 (0.3–2.2)
7–9 (minor dysfunction) (n = 7)	2.6 (1.4–6.3)	0.9 (0.1–2.9)	1.5 (0–4.9)
10–13 (moderate dysfunction) (n = 7)	3.1 (1.1–6.1)	1.5 (0.1–3.9)	1.3 (0.1–3.2)
> 13 (severe dysfunction) (n = 7)	3.5 (0.6–6.1)	2.0 (0.1–5.5)	1.2 (0–3.6)
<i>Time per defecation</i>			
< 30 min (n = 18)	3.5 (1.4–6.3)	1.3 (0.1–3.8)	1.8 (0.3–4.9)
30–60 min (n = 6)	3.4 (1.1–6.1)	2.6 (0.1–5.5)	1.0 (0–2.8)
> 60 min (n = 5)	2.3 (0.6–4.6)	1.0 (0.1–2.7)	0.6 (0–1.8)
<i>Abdominal pain</i>			
Yes (n = 17)	3.3 (1.1–6.3)	1.5 (0.1–5.5)	1.5 (0–4.9)
No (n = 13)	3.2 (0.6–6.3)	1.6 (0.1–3.9)	1.2 (0–3.2)
<i>Difficult rectal emptying</i>			
Yes (n = 17)			
No (n = 13)	3.0 (0.6–6.3)	1.3 (0.1–5.5)	1.6 (0–4.9)
	3.6 (1.4–6.3)	1.9 (0.1–3.9)	1.2 (0.1–3.7)
<i>Headache or perspiration during defecation</i>			
Yes (n = 10)			
No (n = 20)	3.4 (0.6–6.3)	1.9 (0.1–5.5)	1.4 (0–3.6)
	3.2 (1.4–6.3)	1.6 (0.1–3.8)	1.4 (0.1–4.9)
<i>Faecal incontinence at least once per week</i>			
Yes (n = 9)	3.7 (1.6–6.1)	1.9 (0.1–5.5)	1.7 (0–3.6)
No (n = 20)	3.1 (0.6–6.3)	1.4 (0.1–3.8)	1.3 (0–4.9)
<i>Bowel symptom has some or major impact on QOL</i>			
Yes (n = 14)	3.4 (1.1–6.1)	1.8 (0.1–5.5)	1.5 (0–3.6)
No (n = 16)	3.2 (0.6–6.3)	1.5 (0.1–3.8)	1.3 (0–4.9)

Abbreviations: CTT, colonic transit times; GITT, total gastrointestinal transit times; QOL, quality of life.

Discussion

We find that the present study helps defining the usefulness of radiographically determined gastrointestinal or segmental CTT in spinal cord-injured patients. Interobserver variation is very small and reproducibility of GITT was acceptable with dispersion (difference/mean) of 0.28. Reproducibility of right or left CTT was less good with dispersion of 0.66 and 0.69, respectively. Several other studies have shown a significant difference in total gastrointestinal, total colonic or segmental CTT between groups of patients with SCI and healthy volunteers.^{7–10} In our opinion, this makes the method useful as an objective end point when studying the physiological effects of various treatment modalities for neurogenic bowel dysfunction in groups of patients with SCI. The method is, however, severely hampered by its lack of correlation with the most common neurogenic bowel symptoms. Accordingly, results should be interpreted with caution and always supplemented by thorough information about symptoms. The Wexner and his colleagues²⁰ and Vaizey *et al.*²¹ scores for faecal incontinence, the Cleveland Constipation Scoring System¹⁹ and the Neurogenic Bowel Dysfunction Score¹² may be useful for this.²² Furthermore, ongoing work on Spinal Cord Injury Bowel Data Sets may result in easily obtainable and clinically relevant end points for future studies (Drafts for International Spinal Cord Injury Bowel Function Basic and Extended Data Sets have been available at the ISCOS website). Other methods such as scintigraphic assessment of colorectal emptying may be of future use in studies of local treatment for neurogenic bowel symptoms.^{23,24}

Intersubjective variation is large and there is a substantial overlap between transit times in SCI patients and healthy volunteers. This, in addition to the poor correlation between symptoms and transit times, makes the method of very limited value for clinical decision-making in individual patients. We chose to divide the colorectum into the right and the left colon based on the extrinsic parasympathetic innervation from the vagal nerves and the sacral spinal cord. Others have divided the colorectum into three or four segments. Dividing the colorectum into more segments would probably not improve associations to colorectal symptoms and would certainly not improve the reproducibility of transit times.

In conclusion, radiographically determined GITT and right and left CTT are of very limited value for clinical decision-making in individual patients. They may, however, be useful for comparison of bowel function among groups of patients with SCI and for objective evaluation of new treatment modalities but should be complemented by thorough information about bowel symptoms.

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