Original article

Sacral nerve stimulation for faecal incontinence alters colorectal transport

H. B. Michelsen[1], P. Christensen[1,2], K. Krogh[2], M. Rosenkilde[3], S. Buntzen[1], J. Theil[4] and S. Laurberg[1]

[1]Surgical Research Unit, Department of Surgery P, [2]Neurogastroenterology Unit, Department of Gastroenterology and Hepatology V and Department of Surgery P, [3]Department of Radiology and [4]Department of Clinical Physiology and Nuclear Medicine, Aarhus University Hospital, Aarhus, Denmark
Correspondence to: Dr H. B. Michelsen, Surgical Research Unit, Department of Surgery P, Aarhus University Hospital, Tage-Hansens Gade 2, DK - 8000 Aarhus C, Denmark (e-mail: hbn@mail.tele.dk)

Background: Sacral nerve stimulation reduces the frequency of defaecation in patients with faecal incontinence. The aim of this study was to examine the mechanism behind the reduced number of bowel movements in incontinent patients treated with sacral nerve stimulation.

Methods: The study included 20 patients with faecal incontinence and a positive percutaneous nerve evaluation test: 19 women and one man, with a median age of 63 (range 28–78) years. Colorectal scintigraphy was performed to assess colorectal emptying at defaecation before and after implantation. Segmental colorectal transit times were determined using radio-opaque markers.

Results: The median frequency of defaecation per 3 weeks decreased from 56 (range 19–136) to 26 (range 12–78) ($P < 0{\cdot}002$). At defaecation, antegrade transport from the ascending colon decreased from a median score of 8 (range 0–23) to 0 (range 0–11) per cent ($P = 0{\cdot}001$), while retrograde transport from the descending colon increased from a median score of 0 (range 0–14) to 2 (range 0–30) per cent ($P = 0{\cdot}039$). The median defaecation score was unchanged. There was a non-significant increase in median total gastrointestinal transit time from 2·5 (range 0·9–6·2) to 3·3 (range 0·8–6·2) days ($P = 0{\cdot}079$).

Conclusion: Sacral nerve stimulation reduces antegrade transport from the ascending colon and increases retrograde transport from the descending colon at defaecation. This may prolong colonic transit time and increase the storage capacity of the colon.

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Introduction

Sacral nerve stimulation (SNS) is an established treatment for faecal incontinence when conventional treatments have failed[1–5]. In addition to the improved continence, a reduced frequency of defaecation is seen[5–8]. However, the exact mode of action of SNS is unclear. Originally the effect of SNS was thought to be on the pelvic floor and anal sphincters, but reports on this have been variable[1–3,5,7,9–16]. The most consistent finding has been a moderate increase in anal squeeze pressure representing improved external anal sphincter function[1–3,7,9–14]. The effect on the internal anal sphincter has not been clarified[3,11,16]. An effect on the rectum has been proposed, but without agreement[2,5,9,10,12–15]. Furthermore, 24-h manometry has shown an inhibition of the spontaneous rectal motility complexes after meals and on awakening[17]. Another suggestion has been that SNS causes neuromodulation at a spinal or supraspinal level[2,5,18].

The aim of the present study was to examine the mechanism behind the reduced number of bowel movements in incontinent patients successfully treated with SNS, by evaluating colorectal emptying and antegrade and retrograde transport during defaecation before and after implantation.

The Editors are satisfied that all authors have contributed significantly to this publication

Methods

This study included 20 consecutive patients with faecal incontinence who had had a positive percutaneous nerve evaluation test and were awaiting implantation of a permanent electrode and neurostimulator (19 women and one man, median age 63 (range 28–78) years). The aetiology of faecal incontinence was idiopathic faecal incontinence (ten patients), obstetric sphincter lesion (five), anorectal surgery (two), diabetic neuropathy (one), fracture of the lumbar columna with an incomplete lesion of the conus medullaris (one) and irritable bowel syndrome (one). Four of the five patients with a sphincter lesion had had an unsuccessful sphincter repair; the fifth patient, who was 65 years old, did not have a sphincter repair. The patient with irritable bowel syndrome also had severe faecal incontinence.

For stimulation, the lowest amplitude was used with which to achieve optimal clinical results.

The study was approved by the local ethical committee of Aarhus, Denmark. All subjects gave informed consent before participating in the study.

Bowel-habit diaries and Wexner incontinence scores

Patients kept a 3-week bowel-habit diary describing frequency of defaecation, episodes with urge, episodes with incontinence for solid and liquid stools, and days with soiling before and during SNS. The Wexner incontinence score[19] was computed at the time of the scintigraphic procedure before and after the implantation of the sacral neurostimulator.

Scintigraphic procedure

All patients took 2 MBq ^{111}In-labelled polystyrene particles in a glass of water at 08·00 hours on 2 consecutive days (days 0 and 1). On day 2, they arrived at the Department of Clinical Physiology and Nuclear Medicine after fasting for 8 h, and abdominal scintigraphy was performed. If possible, they arrived without having defaecated that morning. They consumed a standard breakfast (a bun with butter and a 150-ml glass of orange juice) and, when they felt the need to defaecate, they used the regular toilet in the hospital. If patients rated the defaecation as 'normal', another abdominal scintigram was taken. If they were unable to defaecate or reported that the defaecation was either smaller or larger than normal, the procedure was repeated on day 3 without taking more ^{111}In-labelled polystyrene particles.

The times of the first and second scintigram, breakfast and defaecation were noted.

The scintigraphic procedure as well as the method for data analysis has been described in detail previously[20,21]. Scintigraphy was performed with the patient in the supine position with a double-headed Picker γ camera with a parallel-hole, medium-energy collimator. Anterior and posterior images were obtained using 20 per cent energy windows over 174- and 247-keV ^{111}In photopeaks respectively. The acquisition time was 10 min (five frames of 2 min).

The scintigraphic procedure was performed before and after implantation of the permanent electrode and neurostimulator. The postimplantation scintigram was performed after optimized treatment.

It has been shown that colorectal transport at defaecation is closely correlated with the subjective assessment of defaecation[20]. Accordingly, scintigraphic results were used for further analysis only if the subject reported that defaecation was normal at scintigraphy both before and during SNS.

Data analysis

The colorectum was divided into four regions on the scintigraphic images: the caecum and ascending colon including the right flexure, the transverse colon, the descending colon including the left flexure, and the rectosigmoid[20]. The regions were delineated manually on both anterior and posterior images. To correct for tissue attenuation, the geometric mean was calculated for each segment as the square root of the product of the anterior and posterior counts[22].

Defaecation score

The total number of counts lost during defaecation was used for quantifying large bowel emptying in one value. The total number of counts evacuated was measured by subtracting the total number of counts within the colorectum after defaecation from the total number of counts before defaecation, and then subtracting the number of counts in each of the four regions before defaecation from the total number lost. Assuming ordered evacuation of the large bowel, the contribution of each colonic segment to the overall evacuation was expressed as a percentage of the segmental counts before defaecation. The contributions of each segment were added to reach a total defaecation score in the range 0–400. For example, a defaecation score of 160 per cent would have indicated that the entire rectosigmoid and 60 per cent of the descending

colon had emptied, and a score of 250 per cent that the entire rectosigmoid, descending colon and 50 per cent of the transverse colon had emptied[20,21,23].

Net antegrade and retrograde transport

Antegrade and retrograde transport was computed for each of the four colorectal regions. Before and after defaecation, the number of counts was determined in each region. None of the patients had retrograde transport to the terminal ileum, so the change in counts within the caecum and ascending colon including the right flexure was computed first. Antegrade transport had occurred if the number of counts was lower after defaecation than before. If the counts were higher after defaecation than before, retrograde transport from the transverse colon had occurred. To describe the antegrade and retrograde transport from the transverse colon, the number of counts in the transverse colon after defaecation was subtracted from the number before defaecation and adjusted for counts received from or given to the ascending colon. Net antegrade transport to the descending colon had occurred if the number was positive and retrograde transport to the ascending colon if it was negative. Similar calculations were performed for the descending colon and the rectosigmoid.

Radiological colonic transit time

The total gastrointestinal transit time and the segmental colorectal transit times were determined using radio-opaque markers, as described by Abrahamsson and colleagues[24].

Statistical analysis

Patients served as their own controls. To compare results before and after implantation, the Wilcoxon matched pairs signed ranks test was used. $P < 0{\cdot}050$ was considered significant.

Results

Thirteen of 20 patients (12 women, one man; median age 66 (range 28–78) years) reported normal defaecation at scintigraphy both before and after implantation. Scintigraphic results from these 13 were used for further analysis. Radiographically determined gastrointestinal and colonic transit times were used from all 20 patients.

Table 1 Wexner incontinence scores and results from bowel-habit diaries per 3 weeks

	Before SNS	During SNS	*P**
Wexner incontinence score ($n = 13$)	16 (8–19)	3 (0–12)	< 0·001
Frequency of defaecation ($n = 12$)	56 (19–136)	26 (12–78)	< 0·002
Episodes with urge ($n = 12$)	28 (0–117)	0 (0–36)	0·001
Episodes with incontinence for liquid and solid stool ($n = 12$)	36 (0–101)	1 (0–28)	< 0·003
Days with soiling ($n = 12$)	18 (2–21)	3 (0–21)	0·021

Values are median (range). SNS, sacral nerve stimulation. *Wilcoxon matched pairs signed ranks test.

Bowel-habit diaries and Wexner incontinence scores

The median defaecation frequency per 3 weeks decreased significantly from 56 (range 19–136) before SNS to 26 (range 12–78) during SNS ($P < 0{\cdot}002$). The median Wexner incontinence score, episodes with urge per 3 weeks, episodes with incontinence for solid and liquid stool per 3 weeks, and days with soiling per 3 weeks all decreased significantly after implantation of the sacral nerve stimulator (*Table 1*).

Colorectal scintigraphy

The median time between scintigrams before and after defaecation was 54 (range 24–108) min before SNS and 45 (range 26–81) min during SNS.

The median time between implantation of the permanent electrode and neurostimulator and the second scintigram was 97 (range 42–758) days.

One of the patients had defaecated early in the morning before both scintigrams.

Defaecation score

The median scintigraphically determined defaecation score was 45 (range 15–104) per cent before and 36 (range 8–216) per cent during SNS ($P = 0{\cdot}305$).

Net antegrade transport at defaecation

The median score for antegrade transport from the caecum and ascending colon was 8 (range 0–23) per cent before and 0 (range 0–11) per cent during SNS ($P < 0{\cdot}001$). There were no significant differences in antegrade transport

Table 2 Luminal antegrade colorectal transport scores before and during sacral nerve stimulation in 13 subjects rating their defaecation as normal on the day of the study

	Scores before SNS (%)	Scores during SNS (%)	*P**
Ascending colon	8 (0–23)	0 (0–11)	< 0·001
Transverse colon	5 (0–109)	0 (0–100)	0·831
Descending colon	10 (0–62)	19 (0–74)	0·414
Rectosigmoid	45 (15–104)	36 (8–216)	0·305

Values are median (range). SNS, sacral nerve stimulation. *Wilcoxon matched pairs signed ranks test.

between the transverse colon, the descending colon and the rectosigmoid (*Table 2*).

Net retrograde transport at defaecation

Retrograde transport at defaecation was observed in five of 13 patients before and in ten during SNS ($P < 0·050$). Before SNS, the retrograde transport was from the transverse colon in one patient and from the descending colon in four patients. During SNS, nine patients had retrograde transport from the transverse colon, seven from the descending colon and one from the rectosigmoid. No retrograde transport was seen from the caecum and ascending colon to the terminal ileum. Retrograde transport from the descending colon increased significantly, from a median score of 0 (range 0–14) per cent to 2 (range 0–30) per cent ($P = 0·039$). Retrograde transport from the transverse colon also increased, but not significantly (*Table 3*).

Radiologically determined colonic transit time

Total gastrointestinal transit time increased, although not significantly, during treatment with SNS from 2·5 (range 0·9–6·2) to 3·3 (range 0·8–6·2) days ($P = 0·079$). The transit time for the ascending colon increased, but not significantly, from 0·5 (range 0–2·1) to 0·7 (range 0·1–2) days ($P = 0·093$). For the descending colon, the transit time increased non-significantly from 0·5 (range 0·2–1·9) to 1·1 (range 0–2·4) days ($P = 0·065$). The transit times for the transverse colon and the rectosigmoid were almost unchanged (*Table 4*).

Table 3 Luminal retrograde colorectal transport scores before and during sacral nerve stimulation in 13 subjects rating their defaecation as normal on the day of the study

	Scores before SNS (%)	Scores during SNS (%)	*P**
Ascending colon	0 (0–0)	0 (0–0)	
Transverse colon	0 (0–15)	2 (0–13)	0·084
Descending colon	0 (0–14)	2 (0–30)	< 0·039
Rectosigmoid	0 (0–0)	0 (0–7)	

Values are median (range). SNS, sacral nerve stimulation. *Wilcoxon matched pairs signed ranks test.

Table 4 Gastrointestinal transit time and segmental colonic transit time determined by radio-opaque markers before and during sacral nerve stimulation

	Time before SNS (days)	Time during SNS (days)	*P*
GITT ($n = 19$)*	2·5 (0·9–6·2)	3·3 (0·8–6·2)	0·079
Ascending colon ($n = 17$)	0·5 (0–2·1)	0·7 (0·1–2·0)	0·093
Transverse colon ($n = 17$)	0·4 (0–1·4)	0·3 (0–1·5)	0·517
Descending colon ($n = 17$)	0·5 (0·2–1·9)	1·1 (0–2·4)	0·065
Rectosigmoid ($n = 18$)	0·5 (0–2·1)	0·4 (0–1·7)	0·284

Values are median (range). *One of the 20 patients had the permanent electrode and neurostimulator explanted before the second examination, resulting in 19 patients with a total gastrointestinal transit time (GITT) before and after sacral nerve stimulation (SNS).

Discussion

This study found that the reduced frequency of defaecation in patients with faecal incontinence successfully treated with SNS was associated with altered colorectal transport during defaecation. Specifically, it found a significant decrease in antegrade transport from the ascending colon, a significant increase in retrograde transport from the descending colon and a trend towards increased retrograde transport from the transverse colon. In contrast, the defaecation score was unchanged.

These results strongly suggest that SNS reduces luminal transport from the right to the left colon and increases retrograde transport in the left colon at defaecation. This probably causes retention of faecal material in the colon. In accordance with the scintigraphic results, a strong trend towards increased total gastrointestinal transit time and transit time for the ascending and descending colon was found.

Supporting the conclusion that changes in colorectal motility contribute to its effect, SNS also benefits patients with faecal incontinence due to anal sphincter lesions or muscular dystrophy[25].

It has been suggested that SNS causes neuromodulation at a spinal level or even more centrally[2,5,18]. Sheldon and colleagues[18] have shown, via transcranial magnetic stimulation, that SNS is associated with a reversible reduction in corticoanal excitability. In their study, SNS induced inhibitory changes in the motor cortex

to the external anal sphincter (corticoanal pathway). The present study supports this hypothesis, as SNS leads to changes in the right colon, which receives parasympathetic innervation from the vagal nuclei located in the brainstem[26]. The effect of SNS is therefore not only due to stimulation of somatic and visceral efferent fibres but must also include neuromodulation at higher levels.

Several studies have examined the physiological changes associated with SNS in faecally incontinent patients. The most consistent finding is a moderate increase in anal squeeze pressure, representing improved external anal sphincter function[1–3,7,9–14]. However, the effect on the internal anal sphincter and on rectal thresholds to distension has been unclear[3,5,11,12,14–16]. SNS has an effect not only on the pelvic floor but also on the entire colorectum and anal canal, and it seems that SNS has minor effects at several levels. The changes in the present study were significant but small; nevertheless, the total effect of SNS is considerable, with a reduction in the frequency of defaecation and improved continence.

Clinically, the effect of SNS on faecal incontinence is the opposite of the effect on constipation, as the frequency of defaecation is decreased in incontinence and, as described by Dinning and colleagues[27], increased in patients with slow-transit constipation. A simple physiological explanation could be that SNS causes a better emptying of the left colon and rectum in both faecally incontinent and constipated patients. However, the present study does not support this hypothesis, as the defaecation score was unchanged after SNS. Instead, it suggests that the effect of SNS on the colon must be different for incontinent and constipated patients. For incontinent patients, there is retention of faecal material in the right colon during defaecation and a trend towards an increased gastrointestinal transit time. For patients with slow-transit constipation, the frequency of defaecation increases and SNS induces pan-colonic propagating waves[27]. Therefore it is important to evaluate the effects of SNS on colorectal physiology separately for various patient groups.

The number of patients in the present study was rather small, and the risk of a type 2 error should be considered. The study would have been strengthened by determining the weight and volume of stool at each defaecation in the 3 weeks before and after SNS, although this was impractical here.

The validity of the scintigraphic method is good, but the inter- and intraindividual variations are large[20]. In a reproducibility study among healthy volunteers[20], antegrade transport from the ascending colon at defaecation was larger on day 2 than on day 1. This cannot explain the results in the present study, where ascending colonic transport was significantly smaller after than before SNS. As the aim was to compare colorectal transport before and after SNS, a control group of asymptomatic subjects was not used.

This study has shown that the decrease in frequency of defaecation in patients successfully treated with SNS is associated with decreased antegrade transport from the ascending colon, and increased luminal retrograde transport from the descending colon and probably the transverse colon. Furthermore, colonic transit times are increased, probably reflecting an improved storage capacity of the colon.

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References

1 Matzel KE, Stadelmeier U, Hohenfellner M, Gall FP. Electrical stimulation of sacral spinal nerves for treatment of faecal incontinence. *Lancet* 1995; **346**: 1124–1126.
2 Vaizey CJ, Kamm MA, Turner IC, Nicholls RJ, Woloszko J. Effects of short term sacral nerve stimulation on anal and rectal function in patients with anal incontinence. *Gut* 1999; **44**: 407–412.
3 Ganio E, Luc AR, Clerico G, Trompetto M. Sacral nerve stimulation for treatment of fecal incontinence: a novel approach for intractable fecal incontinence. *Dis Colon Rectum* 2001; **44**: 619–629.
4 Rasmussen OØ, Christiansen J. [Sacral nerve stimulation in fecal incontinence.] *Ugeskr Laeger* 2002; **164**: 3866–3868.
5 Michelsen HB, Buntzen S, Krogh K, Laurberg S. Rectal volume tolerability and anal pressures in patients with fecal incontinence treated with sacral nerve stimulation. *Dis Colon Rectum* 2006; **49**: 1039–1044.
6 Matzel KE, Kamm MA, Stösser M, Baeten CGM, Christiansen J, Madoff R *et al*. Sacral spinal nerve stimulation for faecal incontinence: multicentre study. *Lancet* 2004; **363**: 1270–1276.
7 Matzel KE, Stadelmeier U, Hohenfellner M, Hohenberger W. Chronic sacral spinal nerve stimulation for fecal incontinence: long-term results with foramen and cuff electrodes. *Dis Colon Rectum* 2001; **44**: 59–66.
8 Matzel KE, Stadelmeier U, Hohenberger W. Innovations in fecal incontinence: sacral nerve stimulation. *Dis Colon Rectum* 2004; **47**: 1720–1728.
9 Vaizey CJ, Kamm MA, Roy AJ, Nicholls RJ. Double-blind crossover study of sacral nerve stimulation for fecal incontinence. *Dis Colon Rectum* 2000; **43**: 298–302.
10 Ganio E, Ratto C, Masin A, Luc AR, Doglietto GB, Dodi G *et al*. Neuromodulation for fecal incontinence: outcome in 16 patients with definitive implant. The initial Italian Sacral

Neuromodulation Group (GINS) experience. *Dis Colon Rectum* 2001; **44**: 965–970.
11 Rosen HR, Urbarz C, Holzer B, Novi G, Schiessel R. Sacral nerve stimulation as a treatment for fecal incontinence. *Gastroenterology* 2001; **121**: 536–541.
12 Kenefick NJ, Vaizey CJ, Cohen RCG, Nicholls RJ, Kamm MA. Medium-term results of permanent sacral nerve stimulation for faecal incontinence. *Br J Surg* 2002; **89**: 896–901.
13 Ripetti V, Caputo D, Ausania F, Esposito E, Bruni R, Arullani A. Sacral nerve neuromodulation improves physical, psychological and social quality of life in patients with fecal incontinence. *Tech Coloproctol* 2002; **6**: 147–152.
14 Jarrett ME, Varma JS, Duthie GS, Nicholls RJ, Kamm MA. Sacral nerve stimulation for faecal incontinence in the UK. *Br J Surg* 2004; **91**: 755–761.
15 Malouf AJ, Vaizey CJ, Nicholls RJ, Kamm MA. Permanent sacral nerve stimulation for fecal incontinence. *Ann Surg* 2000; **232**: 143–148.
16 Ganio E, Masin A, Ratto C, Altomare DF, Ripetti V, Clerico G *et al*. Short-term sacral nerve stimulation for functional anorectal and urinary disturbances: results in 40 patients: evaluation of a new option for anorectal functional disorders. *Dis Colon Rectum* 2001; **44**: 1261–1267.
17 Altomare DF, Rinaldi M, Petrolino M, Monitillo V, Sallustio P, Veglia A *et al*. Permanent sacral nerve stimulation for fecal incontinence and associated urinary disturbances. *Int J Colorectal Dis* 2004; **19**: 203–209.
18 Sheldon R, Kiff ES, Clarke A, Harris ML, Hamdy S. Sacral nerve stimulation reduces corticoanal excitability in patients with faecal incontinence. *Br J Surg* 2005; **92**: 1423–1431.
19 Jorge JM, Wexner SD. Etiology and management of fecal incontinence. *Dis Colon Rectum* 1993; **36**: 77–97.
20 Krogh K, Olsen N, Christensen P, Madsen JL, Laurberg S. Colorectal transport in normal defaecation. *Colorectal Dis* 2003; **5**: 185–192.
21 Christensen P, Olsen N, Krogh K, Laurberg S. Scintigraphic assessment of antegrade colonic irrigation through an appendicostomy or a neoappendicostomy. *Br J Surg* 2002; **89**: 1275–1280.
22 Hardy JG, Perkins AC. Validity of the geometric mean correction in the quantification of whole bowel transit. *Nucl Med Commun* 1985; **6**: 217–224.
23 Krogh K, Olsen N, Christensen P, Madsen JL, Laurberg S. Colorectal transport during defecation in patients with lesions of the sacral spinal cord. *Neurogastroenterol Motil* 2003; **15**: 25–31.
24 Abrahamsson H, Antov S, Bosaeus I. Gastrointestinal and colonic segmental transit time evaluated by a single abdominal x-ray in healthy subjects and constipated patients. *Scand J Gastroenterol Suppl* 1988; **152**: 72–80.
25 Buntzen S, Rasmussen OO, Ryhammer AM, Sorensen M, Laurberg S, Christiansen J. Sacral nerve stimulation for treatment of fecal incontinence in a patient with muscular dystrophy: report of a case. *Dis Colon Rectum* 2004; **47**: 1409–1411.
26 Keighley MRB, Williams NS. *Surgery of the Anus, Rectum and Colon*. WB Saunders: London, 1999; 1–16.
27 Dinning PG, Fuentealba SE, Kennedy ML, Lubowski DZ, Cook IJ. Sacral nerve stimulation induces pan-colonic propagating pressure waves and increases defecation frequency in patients with slow-transit constipation. *Colorectal Dis* 2006; **9**: 123–132.