

Difficulty with evacuation after spinal cord injury: Colonic motility during sleep and effects of abdominal wall stimulation

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Abstract—Difficulty with evacuation (DWE) is common in individuals with spinal cord injury (SCI). Numerous studies have concluded that constipation, impaction, and incontinence cause significant morbidity and, collectively, constitute an important quality-of-life issue in individuals with SCI. Colonic motor activity was assessed using a solid-state manometry probe. We report here that colonic pressure activity is depressed during sleep compared to that observed in able-bodied controls. In addition, pressure activity was decreased during sleep compared to pre-sleep and post-sleep. We suspect that this may contribute to delayed colon transit time after SCI. In addition, since contraction of the abdominal wall musculature plays a role in normal defecation, we assessed whether an abdominal belt with implanted electrodes would improve DWE. In this respect, we demonstrated that neuromuscular stimulation of the abdominal wall improves a number of indices of defecatory function, including time to first stool and total bowel care time.

Key words: bowel care, colon, constipation, difficulty with evacuation, motility, neuromuscular stimulation, spinal cord injury.

INTRODUCTION

Difficulty with evacuation (DWE) is a common complication of spinal cord injury (SCI). DWE frequently

results in constipation, impaction, and incontinence; collectively, these gastrointestinal sequelae constitute a major quality-of-life issue for individuals with SCI. DWE has been attributed to prolongation of the colonic transit time in these individuals. This has been demonstrated with a number of techniques, including radio-opaque markers and nuclear scintigraphy [1-3]. Although the physiological basis for this prolongation of transit time is unclear, an imbalance between parasympathetic and sympathetic inputs to the colon has been proposed. Moreover, the optimal management of DWE remains problematical.

Abbreviations: DWE = difficulty with evacuation, SCI = spinal cord injury, SI = spinally intact, TBC = time for total bowel care, TFS = time to first stool, VAMC = Department of Veterans Affairs Medical Center.

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To further define the pathophysiology of delayed transit time, we report in this article long-term colonic motility studies in subjects with SCI and compare the results to those in able-bodied controls. We obtained these measurements using a novel technique, in which a manometric probe is affixed to the left colon using a colonoscope. The effects of sleep on colonic pressure activity are reviewed here. In addition, this article summarizes recent work directed toward the management of DWE. Contraction of the abdominal wall musculature is known to play an important role in defecation by increasing intra-abdominal pressure. Inasmuch as some individuals with SCI (depending on the level of injury) may lack voluntary control of their abdominal musculature, we assessed whether an abdominal belt with implanted electrodes would improve indices of defecation. Our data indicate that neuromuscular stimulation of the anterior abdominal wall may be a useful adjunct to bowel care in individuals with SCI.

COLONIC MOTILITY STUDIES

Subjects

Fourteen healthy male volunteers were recruited for the study (**Table**). Of the eight individuals with SCI, three had tetraplegia and five had paraplegia. The mean age was 59 years (range 23–67), and mean duration of injury was 13 years (range 2–33). These subjects all reported having fewer than 2 bowel movements per week, and all had a regular bowel care program for at least 6 months before they enrolled in the study. Six individuals (mean age 57 years) who were spinally intact (SI) were also studied. The SI subjects recruited for study

were in good health, had no previous history of gastrointestinal surgery, and had normal physical examinations on recruitment. The Institutional Review Board of the Bronx Veterans Affairs Medical Center (VAMC) granted approval of the study protocol before the subjects were recruited, and informed consent was obtained before their enrollment in the study. Medications that may alter colonic motility and hemostasis (e.g., warfarin, aspirin) were withheld prior to the study.

Experimental Design

Subjects with SCI were admitted to the SCI Service for facilitation of bowel preparation for the colonoscopy. Bowel preparation consisted of electrolyte lavage solutions and/or phosphate enemas, with tap water enemas on the day of the procedure. The SI subjects were prepared in a similar manner and were admitted on the day of the procedure. Colonoscopy was performed prior to the study, and all the patients had normal colonic examinations. A solid-state manometric catheter with four pressure transducers that were spaced approximately 10 cm apart was used for this study (Gaeltec, Dunvegan, UK). The manometric probe was attached to a portable recorder (type 7-MPR, Gaeltec), powered by four alkaline batteries. After completion of the study, the data were uploaded to a computer for data storage and analysis. Fixation of the manometric probe was accomplished as previously described by Fajardo et al. [4]. In brief, a silk 4-0 thread was attached to the tip of the manometric catheter. In turn, the thread was looped around the base of an endoclip (Olympus MD 50, Olympus Inc.) and loaded on an endoscopic clipping device (Olympus Inc.) that was introduced through the biopsy channel of a colonoscope (Olympus Inc). The colonoscope and the probe

Table.

Demographics of subjects with SCI in motility study.

Subject	Age	SCI Level	Duration of Injury (Years)	Mechanism of Injury
1	63	C5–7	4	Fall
2	67	C5–7	2	Cervical stenosis
3	58	C5–6	33	Motor vehicle accident
4	63	L3–S1	26	Fall
5	57	T5–7	20	Motor vehicle accident
6	53	T10	7	Gunshot wound
7	56	T10	11	Transverse myelitis
8	23	T10	3	Gunshot wound

SCI = spinal cord injury

were advanced under direct vision up to the splenic flexure. With the use of fluoroscopy, it was assured that the last pressure sensor was at least 10 cm proximal to the anal verge. Once a suitable mucosal fold was identified, the thread attached to the tip of the probe was clipped to the bowel wall. The colonoscope and the clipping device were then withdrawn. The distal end of the probe outside the colon was taped securely at the gluteal region to prevent accidental retraction. A flat plate of the abdomen confirmed the placement of the clipped probe at the region of the splenic flexure. The portable recorder was connected to a shoulder sling, permitting mobility. The subjects were given diaries and were instructed to record their sleep cycle. No probe was dislodged during bowel movement in any of our patients. The SCI subjects stayed in the hospital overnight in a hotel-type room that is used to accommodate relatives and/or patients.

Analysis of Data

The recordings were analyzed with the software program AMBB (Gaeltec). Criteria for waves to be included in the analysis include an amplitude of >8 mm Hg, and duration of >3 s [5]. A motility index (defined as the product of the mean amplitude and percentage of activity) was calculated for the following time periods: 1 hour pre-sleep, sleep, and 1 hour post-sleep. Significance of the differences within groups and between groups was determined using Student's *t*-test for paired and unpaired samples, respectively.

Results

During sleep, the motility index was significantly lower in subjects with SCI compared to that in SI individuals (1.5 vs. 5.8, $p < 0.008$). In subjects with SCI, there was a significant decrease in the motility index during sleep compared to pre-sleep (1.5 vs. 2.8, $p < 0.02$) and post-sleep (1.5 vs. 4.3, $p < 0.03$). A similar trend was observed in SI subjects, but the difference was not statistically significant.

NEUROMUSCULAR STIMULATION OF ABDOMINAL WALL

Subjects

Eight subjects with SCI (six with tetraplegia, two with paraplegia) were recruited for this study. All were male and had an average age of 48 ± 14 years. The mean

duration of injury was 13 ± 8 years. All subjects had fewer than two spontaneous bowel movements per week and were on a stable bowel care regimen at the time of the study. As in the above study, the Institutional Review Board of the Bronx VAMC had granted approval of the study protocol before the subjects were recruited, and informed consent was obtained prior to their enrollment in the study.

Methods and Experimental Design

An abdominal belt with embedded electrodes (Bioflex Garments, Bioflex Inc.) was wrapped around the subject at the level of the umbilicus. It was used in conjunction with the subjects' regular bowel care, but activation of the device was randomized. The subjects did not know whether the device was activated. Subjects employed the belt for a total of six bowel care sessions over 2 weeks (during three sessions, the belt was activated; during three sessions, the belt was not activated). The following durations were measured (in minutes): time to first stool (TFS) and time for total bowel care (TBC). TFS was defined as the time from device activation (or sham activation) to passage of first fecal material. TBC was defined as the time from device activation (or sham activation) to an empty rectum on digital examination. Significance of the differences in these parameters was evaluated by the Student's *t*-test for paired and unpaired samples.

Results

Activation of the abdominal belt resulted in a significant reduction in both TFS ($p < 0.005$) and TBC ($p < 0.01$) when SCI subjects were grouped independent of the level of injury (**Figure 1**). Subgroup analysis revealed that TFS and TBC were significantly shortened in the six subjects with tetraplegia, but not in the two subjects with paraplegia (**Figure 2**).

DISCUSSION

The physical and psychological burdens associated with DWE after SCI have been repeatedly stressed [6–8]. Several mechanisms have been proposed to explain DWE. De Looze et al., using radio-opaque markers in individuals with SCI, proposed that the cause of constipation was prolonged transit time rather than loss of rectal sensation or dyssynergic pelvic floor contraction [9]. In part, the prolonged transit time in persons with SCI may

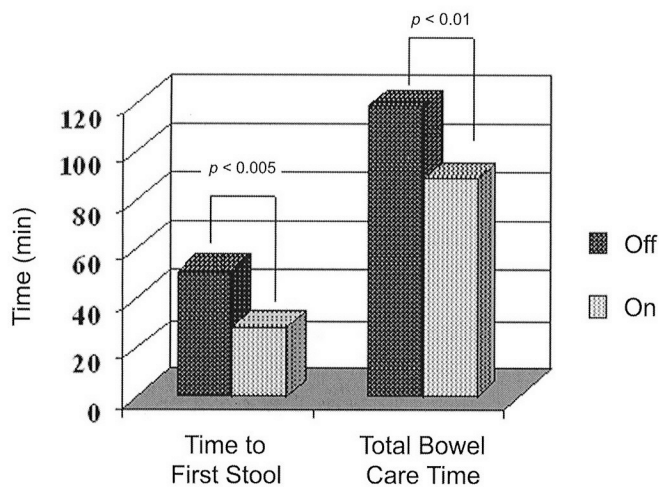


Figure 1.

Effect of abdominal belt on time to first stool and total bowel care time in SCI subjects regardless of level of injury. Data represent mean of 3 sessions with and without activation of electrodes.

arise as a result of depressed propulsive forces in the colon during sleep. We have previously reported similar findings after food ingestion [10]. Together, these findings may help to explain DWE after SCI and suggest that treatment of DWE requires measures that are prokinetic, i.e., agents or devices that increase colonic motility. Colonic function, in general, is modulated by the enteric nervous system and the autonomic nervous system. Because parasympathetic stimulation is known to increase colonic contractility, motility, and tone, it has been postulated that there is a relative or absolute decrease in parasympathetic input to the colon. Our finding that colonic motility is depressed during and after sleep in subjects with SCI is consistent with this hypothesis. As a result, it may be inferred that agents or devices that enhance parasympathetic tone (e.g., neuroprosthetic stimulation of the sacral nerves [11] or pharmacological interventions, such as neostigmine [12]) may be important adjuncts in the management of DWE after SCI. Further studies are needed to explore the potential of these interventions.

Another approach, abdominal wall stimulation, also appears promising. Use of an abdominal belt for delivering electrical stimulation to the muscles of the anterior abdominal wall was based on the established role played by these muscles during defecation in SI individuals. It has been documented that, in addition to relaxation of the anal sphincters and colonic peristalsis, normal defecation

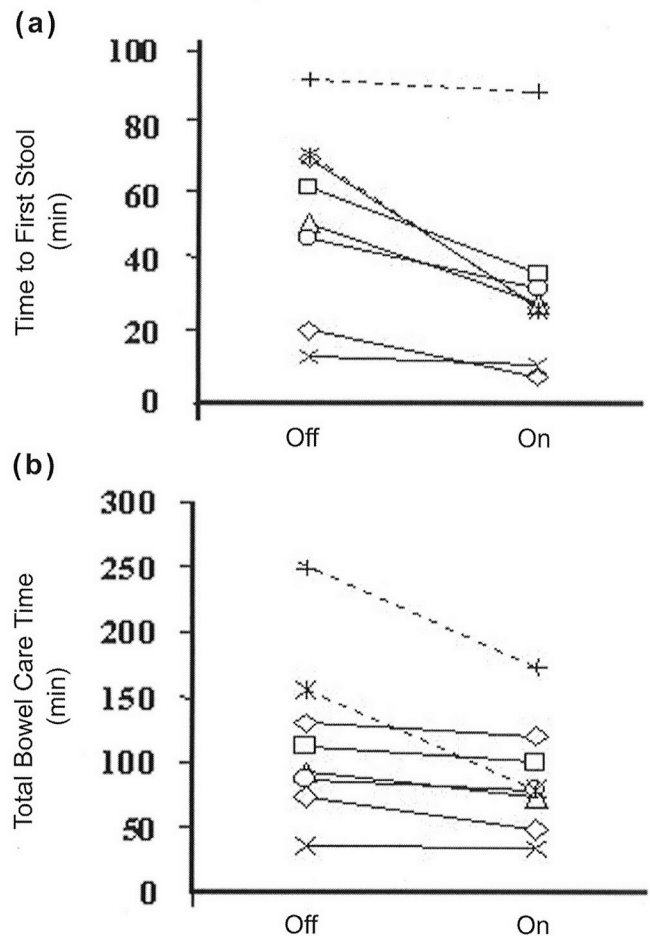


Figure 2.

Effect of abdominal belt on (a) time to first stool and (b) total bowel care time in subjects with tetraplegia (solid lines) and paraplegia (broken lines). Decrease in parameters during muscle stimulation was statistically significant ($p < 0.01$ and 0.02 , respectively) in subjects with tetraplegia, but not in those with paraplegia.

depends on the ability to increase intra-abdominal pressure by voluntarily contracting the rectus abdominis muscles. The lower thoracic nerves T7–12 innervate these muscles. Lesions of the spinal cord above T7 would thus be expected to interfere with volitional control of intra-abdominal pressure. Although the number of subjects in our study is limited, our data support this concept. Parameters of defecation were significantly improved only in the subjects with tetraplegia and not in those with paraplegia who had lower lesions. However, given the small number of subjects with paraplegia recruited, such a conclusion should be considered tentative. In order to be sufficiently powered, a larger study with more subjects with paraplegia is required.

CONCLUSION

The data presented in this paper add to our understanding of a number of issues related to DWE after SCI. In terms of pathogenesis, our results indicate that prolonged colonic transit time after SCI is, in part, due to depressed peristalsis and that colonic hypokinesia is especially pronounced during periods of sleep. From the management standpoint, adjunctive measures directed at increasing intra-abdominal pressure during bowel care might be helpful in alleviating DWE. Although electrical stimulation of the abdominal muscles was the focus of our work, it is conceivable that simple physical measures such as abdominal binders or other compressive devices might have comparable efficacy.

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