Constipation Associated with Chronic Spinal Cord Injury: The Effect of Pelvic Parasympathetic Stimulation by the Brindley Stimulator

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Summary

Ten subjects with severe constipation due to complete spinal cord injury (SCI) had prolonged oro-anal transit time ($p < 0.01$), diminished faecal water content ($p < 0.05$) and a reduced frequency of defaecation ($p < 0.01$) compared to 10 non-SCI subjects. Paraplegics with an implanted Brindley S234 anterior sacral nerve root stimulator had a significant increase in frequency of defaecation ($p < 0.01$), compared to the SCI group while the faecal water content was less although not significantly so. The Brindley stimulator group also showed a more rapid colonic transit than the SCI group but this did not reach statistical significance. SCI is associated with constipation which therefore appears to be favourably influenced by the Brindley S234 anterior nerve root stimulator. The effects produced are compatible with stimulation of left colonic motility, which facilitates the emptying of the distal colon, but also suggest that part of the response restricts transit in some areas of the colon or rectum. Since the motility changes induced by the Brindley stimulator do not affect the right colon a relatively greater residence time of the faecal bolus in this part of the large bowel would enhance water absorption.

Key words: Paraplegia; Colonic transit time; Faecal water; Implant; Stimulator.

Constipation is commonly present after spinal cord injury (SCI) and usually takes a chronic intractable form.¹ This study assesses the degree of constipation in a group of SCI subjects by measuring the oro-anal transit time, the faecal water content and the frequency of defaecation, and comparing the results obtained with a group of non-spinal injured control subjects. In a third group of subjects a Brindley S234 anterior sacral nerve root stimulator had been implanted.² These subjects were similarly studied to assess the effect of activating the sacral parasympathetic nerve supply to the distal colon and rectum.

Brindley introduced the implantable anterior sacral nerve root stimulator for bladder control in selected paraplegic subjects.² After suitable lumbo-sacral laminectomy the appropriate anterior sacral nerve roots are placed within the electrodes. The electrodes are attached to a passive subcutaneous receiver which is activated by an external radio-frequency transmitter. Using this device it is possible to empty the bladder or close the urethra.³ It is also possible to activate the sigmoid colon and pelvic floor.⁴ In this study the stimulator parameter of signal frequency, impulse duration and intensity plus the stimulation free time gaps were regulated for optimum bladder function.

Binnie *et al.*⁵ have shown sequential S2, 3 and 4 anterior nerve root stimulation increases the motility responses from the transverse colon to the rectum in paraplegic subjects. The greatest response was to S3 root stimulation which could empty the left colon by a distal motility gradient. The effects produced are compatible with stimulation of left colon motility and the emptying of the distal bowel. They also suggest however that part of the response may restrict transit in some areas of the colon and rectum.

In view of the pronounced motor effects on distal bowel function it was decided to compare paraplegic subjects treated with a Brindley stimulator with untreated spinal injury subjects in respect of parameters of intestinal motor function such as transit time, faecal water content and frequency of defaecation.

Subjects

Three groups were studied as follows: (a) a control group of 10 healthy volunteers comprising of 8 males and 2 females with no history of gastrointestinal disease or SCI, mean age 29.1 years with a range 22–38 years; (b) the second group of 10 subjects comprising 9 males and 1 female had complete SCI ranging from level C4 to T10. Their mean age was 34.1 years with a range from 20–45 years. The mean time since SCI was 8.1 years (range 1–20 years); and (c) the third group consisted of 7 SCI subjects with implanted sacral anterior nerve root 'Brindley' stimulators. There were 6 males and 1 female in this group with a mean age of 36.3 years ranging from 20–50 years. The levels of SCI ranged from C5 to T3 with a mean time since injury of 7.4 years (range 1–21 years) and mean time since stimulator implant of 2.6 years (range 1–5 years).

Methods

Subjects entering the study took no laxatives for at least 2 days prior to the study and refrained from aperients throughout the study period. They were fasted for 8 hours before commencing the transit studies and after completion of the oro-caecal transit time continued on a normal diet.

Oro-caecal transit time

The method used was that of Bond *et al.*⁶ since it was easy to repeat in subjects with a SCI. They were prepared for oro-caecal transit time estimation by an 8 hour overnight fast before a baseline end expiratory 20 ml breath sample was taken prior to breakfast. Ten grams of lactulose in 15 ml water was given with a standardised

breakfast of cereal with milk followed by tea or coffee plus toast with preserve (500 calories). The orally administered nondigestible carbohydrate lactulose is fermented in the caecum and within 8 minutes of reaching the caecum the product gas hydrogen appears in the exhaled breath.⁶ The patient did not eat or drink and smoking was not permitted thereafter until the test was completed. The end expiratory breath samples were repeated every 15 minutes until the rise in breath hydrogen due to the arrival of the lactulose in the caecum was recorded.

Oro-anal transit time

This was estimated by the single ingestion of fifty 2 mm cube radio-opaque 'Hinton' pellets.⁷ The stools were collected from then onwards, were stored in a sealed container with the time and date recorded, and subsequently X-rayed to reveal the numbers of the markers passed. This process was continued until at least 80% of the pellets had been passed. The time to the 80% recovery point was taken as the oro-anal transit time. In the paraplegic subjects the stool collection was by manual evacuation plus occasional spontaneous rectal evacuation. A rectal digital examination was performed each day after breakfast and any rectal residue was collected into the stool specimen containers.

Faecal water content

The faecal water content was derived by weighing the stool specimen before and after freeze drying using the technique as described by Eastwood.⁸

Frequency of Defaecation

The frequency of defaecation was noted from the time of ingestion of the transit markers until completion of the oro-anal transit time.

Statistical analysis

As an alternative to the usual one way analysis of variance the Kruskal-Wallis test was used to analyse the data for the three groups in each of the four investigations performed. Where this was significant pairwise Mann-Whitney-Wilcoxon tests were performed with the Bonferroni correction. The Mann-Whitney-Wilcoxon test gives 95% confidence intervals (c.i.) for the difference in medians and these are quoted where significant.

Results

Oro-caecal transit time

There was no significant difference between the oro-caecal times for the controls (2.95 hrs $\pm$ SEM 0.15 hrs) and the SCI group (3.4 hrs $\pm$ SEM 0.34 hrs ($p > 0.05$)) or between the controls and the Brindley stimulator group (3.4 hrs $\pm$ SEM 0.34 hrs ($p > 0.05$)). Similarly there was no significant difference between the SCI group and the Brindley stimulator group ($p > 0.05$).

Figure 1 Oro-anal transit time in controls, spinal cord injury and Brindley stimulator groups. The means and standard error of the means are shown. The number of superimpositions of data points are as indicated.

Figure 2 Faecal water content of controls, spinal cord injury and Brindley stimulator groups. The means and standard error of the means are shown. The number of superimpositions of data points are as indicated.

Oro-Anal transit time

The oro-anal transit time (Fig. 1) in the controls was 68.7 hours $\pm$ SEM 7.6 hours and was significantly shorter than in the SCI group which was 187.3 hours $\pm$ SEM 27.7 hours ($p < 0.01$) (c.i. -166.0, -66.0). The control oro-anal transit time was also significantly shorter than that in the Brindley implant group 135.6

Figure 3 Frequency of defaecation of controls, spinal cord injury and Brindley stimulator groups. The means and standard error of the means are shown. The number of superimpositions of data points are as indicated.

hours $\pm$ SEM 7.5 hours ($p < 0.01$) c.i. -94.0 , -34.5) (Fig. 1). The oro-anal transit time in the Brindley stimulator group was shorter than in the spinal cord injury group but not significantly so.

Faecal water content

There was a significant difference between the faecal water content (Fig. 2) of the controls ($69.7 \pm$ SEM 0.7%) and the SCI group ($63.9\% \pm$ SEM 1.6%) ($p < 0.05$) (c.i. 2.0 , 10.0). There was similarly a difference between the controls and the Brindley stimulator group ($58.1\% \pm$ SEM 0.9%) ($p < 0.01$) (c.i. 9.0 , 14.9) (Fig. 2). The faecal water content in the SCI group was not significantly higher than in the Brindley stimulator group.

Frequency of defaecation

The frequency of defaecation (Fig. 3) or stools per day was significantly different between the controls $1.12/\text{day} \pm$ SEM $0.14/\text{day}$ and the spinal cord injury group $0.37/\text{day} \pm$ SEM $0.07/\text{day}$ ($p < 0.01$) (c.i. 0.5 , 1.1) and between the spinal cord injury group and the Brindley implant group $0.78/\text{day} \pm$ SEM $0.08/\text{day}$ ($p < 0.01$) (c.i. -0.67 , -0.17). There was however no significant difference between the frequency of defaecation in the controls and the Brindley implant group.

Discussion

Studies on human subjects with low spinal cord or sacral lesions by Denny-Brown and Robertson⁹ concluded that the mechanism controlling defaecation was medi-

ated through the sacral spine and its peripheral nerves which is in agreement with later works.^{10, 11} The absence of postprandial colonic myoelectrical and motor activity in the colon has been demonstrated by Glick *et al.*¹ The absence of the postprandial response is thought to be due to lack of parasympathetic neural continuity to the left colon and rectum via the sacral outflow in the 2nd, 3rd and 4th anterior sacral nerve roots.¹² In keeping with this theory, left colonic and rectal stasis has been shown to be one of the main causes of delay in gastrointestinal transit time following SCI.¹³

Since vagal innervation is not compromised in SCI it might be expected that the oro-caecal transit times in SCI subjects would not be changed compared with non-spinal injured controls. The results in this study showed no significant difference in small bowel transit time between controls and the SCI group or between controls and the Brindley stimulator group. The Brindley stimulator acts on the anterior roots of the sacral nerves S2-4 and thus affects only the sacral parasympathetic outflow and would not directly influence the foregut. There was no difference between the oro-caecal transit times in the SCI group and the Brindley stimulator group.

The presence of constipation with slow transit in SCI subjects is now accepted.^{1, 13-18} In this study there was a significant prolongation of oro-anal transit time between controls and both the SCI group and the Brindley stimulator group. The oro-caecal times were normal thus leaving the delay to be accounted for by prolonged colonic transit time. The colonic delay has been recorded in the left colon and rectum.¹³ The Brindley stimulator activates the sacral parasympathetic outflow and might be expected to influence the left colon and rectum. The calculated mean colonic transit time in the Brindley stimulator group was 132.2 hours $\pm$ SEM 7.4 hours while the mean colonic transit time in the SCI group was 183.9 hours $\pm$ SEM 27.6 hours. This difference was however not statistically significant.

The frequency of defaecation was reduced in the SCI group compared with the controls but returned to a frequency comparable to the control one with the Brindley stimulator. The increased frequency of defaecation in the Brindley stimulator group when compared to the SCI group possibly reflects the motor influence of the stimulator on the left colon and rectum.⁵

The faecal water content was significantly less in both the SCI group and the Brindley stimulator group when compared to controls. The overall colonic transit time is shorter and frequency of defaecation is increased for the Brindley group compared to the SCI group while the faecal water content is paradoxically less in the Brindley group, although this latter finding did not achieve statistical significance with the Bonferroni correction. A possible explanation for the reduced faecal water content in the Brindley group may lie in the pattern of colonic motility induced by the stimulation of the left colon and rectum.

Previous results⁴ suggest that the left colon is made to contract in a manner resembling peristalsis which would promote colonic and rectal emptying by the Brindley stimulator, although the pelvic floor which also contracts would tend to prevent emptying.¹⁹ The pattern of motility produced in the colon when the stimulator is activated⁵ suggests relative hold-up in the right colon since the transverse colon motility, although stimulated, is affected much less than that of the left colon which has its maximum activity beginning at the splenic flexure as the pelvic parasympathetic nerves S2, 3 and 4 to the left colon are stimulated. These effects alter

the transit of the faecal bolus in different parts of the colon. Non-physiological hold-up in the distal transverse colon would encourage the absorption of water in the right colon resulting in a more firm stool. Once beyond the splenic flexure, the motility encourage by the Brindley stimulator would compensate for any proximal delay and increase the frequency of defaecation and reduce the total colonic transit time.

The predominant effect of the Brindley stimulator on colonic function is therefore the more frequent passage of a formed stool associated with a more rapid colonic transit time. It may prove possible in the future to adapt the Brindley stimulator, not only for urinary bladder control, but also for improvements selectively in the bowel function of paraplegic patients.

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