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Effects of Thoracic Spinal Cord Transection on Colonic Motor Activity in Rats

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Summary

The resting colonic motor activity before and consecutively after spinal cord transection was recorded in male Sprague-Dawley rats. Recording probes were anchored surgically in the ascending and descending colon. Pressure changes were recorded on a dynograph using a low compliance perfusion system. A motility index took into account the amplitude, duration and frequency of contractions. Following a baseline recording animals were subjected either to spinal cord transection at T_4 *level or a sham operation. The recording sessions continued regularly on alternate days for the observation period of 3 weeks. Transection of the thoracic spinal cord markedly reduced the motility index of the distal colon on the first postoperative day. However, the motor activity gradually returned to pre-operative values after 7 days. Sham surgery did not influence the motor activity. These findings suggest that colonic motor activity is influenced by spinal shock and probably by different neural mechanisms mediating proximal and distal activities of the colon in rats.*
Key words: *Spinal cord injuries; Colonic motor activity; Rat experiments.*

Introduction

Several studies have investigated colonic dysfunction associated with spinal cord injury. Connell *et al.* (1963) found that the resting unstimulated motor activity of the pelvic colon was reduced in patients with high cord transection but was significantly increased in those with low cord lesions. Poor colonic compliance was demonstrated in thoracic spinal cord injury (Meshkinpour *et al.*, 1983). The intracolonic pressure increased rapidly to a mean value of 35 mmHg with as little as 300 ml of water infused, whereas in normal controls this pressure was not achieved until 2200 ml of water had been introduced into the colon. In another group of patients with thoracic spinal cord

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injury colonic motor and myo-electrical activities were recorded in a resting state and after ingestion of a meal. The patients showed the baseline colonic motor activity to be similar to that observed in the control population but failed to demonstrate the postprandial increase as in normal subjects. However, all patients included in these studies were beyond the stage of spinal shock with the post-injury duration ranging from 3 months to 20 years, and therefore the earlier changes following cord injury were not observed. In the present study, resting colonic motor activity in rats was recorded before and after thoracic spinal cord transection to determine the acute effects of cord injury and the course of possible changes. A preliminary report of these findings has been presented elsewhere (Meshkinpour *et al.*, 1984).

Methods

Male Sprague-Dawley albino rats weighing 288 ± 36 grams were used. The animals had free access to water and Purina Rat Chow (Check-R-Board, Novi, Michigan). Each animal was anaesthetised with an intraperitoneal injection of 250 mg/kg chloral hydrate, the abdomen opened by a midline incision and the colon exposed. The recording probe was a 19 cm segment of polyethylene tubing (PE-90, Clay-Adams Intromedic, Parsippany, New Jersey) with an internal diameter of 0.86 mm and a side opening of 0.5 mm located 1.0 cm from the end of the catheter. Recording probes were introduced into the proximal and distal colon through a 2 mm incision. They were secured with encircling ligatures, while maintaining the side openings orientated toward the colonic lumen. The proximal recording site was therefore 2–3 cm distal to the caecum and the distal one was about 5–6 cm proximal to the anus. Care was taken not to damage the parallel vasculature and to maintain the organs in their *in situ* positions. The recording probes were led under the skin and brought out at the back of the neck where 4 cms of the tubing were left exposed. The abdominal wall was closed and the animal returned to its home cage to recover.

The initial recording of colonic motor activity was performed at least 24 hours after surgery. Following a baseline recording, the animals were subjected either to spinal cord transection at T_4 level or a sham operation under deep chloral hydrate anaesthesia. The spinal cord was transected by a knife after laminectomy. Sham-operated rats also underwent laminectomy but without subsequent cord transection. Recordings were continued every other day during the survival period.

All recordings were performed during morning hours after a 24-hour fast. Following an initial 15 minute period of stabilisation, recording was performed for 20 minutes in each session. Each pressure probe was perfused at the rate of 0.5 ml of water per minute by a low compliance pneumohydraulic capillary system (Arndorfer Medical Specialities, Greendale, Wisconsin). Intraluminal pressure changes were recorded by a volume displacement transducer (Type 4327-I Bell and Howell, Pasadena, California) and a rectilinear dynograph (Beckman Instruments, Fullerton, California) which was calibrated before each study. All records were coded and analysed blindly by one observer (DH) to minimise errors that might result from variations in interpretation of the con-

tractions or artifacts. The motor activity of the colon was quantified by determining the number of waves, their amplitude and duration. A motility index (MI) was calculated as follows (Deller and Wangel, 1965):

$$\text{Motility Index} = n\ (A \times D/(T \times 10)$$

in which A = amplitude, D = duration, T = recorded time in minutes, and n = number of waves during T. To avoid artifactual errors, waves of less than 3 mmHg were excluded from analysis (Bloom *et al.*, 1968). Each peak of a complex wave was counted as one wave.

The mean motility indices of each postoperative period were compared with those of the pre-operative period. Postoperative values of the cord transected groups were also compared with values obtained from the sham operated group. Student's t-test for paired data was used to analyse the significance of the differences of the mean values.

The spinal cord transected animals received regular skin and bladder care. Somatic reflex activity was tested daily by pinching the foot or tail and observing the responses. Postmortem examination was performed to confirm the location of the recording probes in the colon and the completeness and the level of spinal cord transection.

Results

Twenty-three animals had spinal cord transections and seven had sham operations. Spinal cord transected animals were studied for 20 ± 4 days after surgery. The findings of colonic motor activity are illustrated in Figure 1. Prior to spinal cord transection the motility index of the distal colon was significantly higher than that for the proximal one. Thoracic spinal cord transection markedly reduced

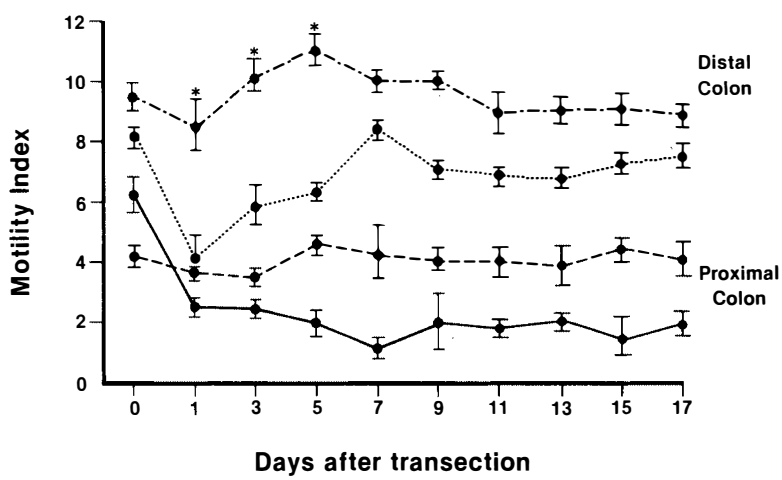

Figure 1. Colonic motor activity in rats before and after T_4 spinal cord transection. Mean motility indices of the distal colon in spinal cord transected (.....) were lower than sham operated (●–·–·–●) animals. (*) denotes a P value of <0.05. The values for the proximal colon were not significantly different in the sham operated (●–·–·–●) and spinal cord transected (——) animals.

the motility index in the distal colon. The index dropped sharply 24 hours after transection, then gradually returned to the preoperative value in seven days and remained stable for the rest of the observation period. The mean motility indices of the distal colon in spinal cord transected animals were significantly less ($P < 0.05$) than those of the sham operated animals in the first, third and fifth postoperative days. In the proximal colon, the impact of the spinal cord transection was not significant. Sham surgery did not influence the proximal or distal colonic motor activity significantly.

Somatic reflex activity was diminished on the first day after spinal cord transection. Minimal or no movements were noted while pinching the foot or tail. By the third day, pinching the foot elicited ipsilateral flexion of the leg and pinching the tail elicited contraction of the base of the tail. Gradually the reflexes became hyperactive with lower threshold. Pinching the foot induced bilateral leg flexion or even repeated bilateral leg kicking and pinching the tail induced stronger contractions of the tail and bilateral leg movements.

Discussion

Thoracic spinal cord transection results in transient failure of reflexes (spinal shock) in the lower extremities, followed by return and progressive exaggeration of reflex activity. Afferent influence may alter the course of recovery. The factors in spinal shock are loss of facilitation from above the transection, release of inhibitory reflexes below the level of the transection, and degeneration of ascending neurones. Recovery of ascending neurones from axonal degeneration, recovery of interneurones from loss of mitochondria in their terminals and release from descending inhibition contribute to the return of reflex activity. The late hyperreflexia is chiefly due to replacement of degenerated terminals by sprouts from afferent axons and to recurrent facilitation. Hypersensitivity of partially denervated neurones may also play a role (Chamber *et al.*, 1973; Yu *et al.*, 1981). In the present study complete transection of the thoracic spinal cord had a marked impact on the motor activity of the distal colon in rats. Reduction of the motor activity was most prominent on the first postoperative day and gradually recovered to preoperative levels by the end of the first week. The transiently decreased motor activity could probably be considered a manifestation of spinal shock in which the connections of supraspinal autonomic centres and segmental outflow to colon are interrupted. However, colonic activity did not become hyperactive in the later stage as did the somatic reflexes. This finding suggests that colonic activity is not affected by the late reorganisation of the spinal cord below the level of the transection.

We found that the motility index of the proximal colon was lower than that of the distal colon prior to cord transection. It is conceivable that the smaller diameter of the distal colon generates contractions of higher amplitude and thus increases the motility index. This may account for the negligible changes in proximal colonic activity recorded after cord transection. However, it is possible that different neural mechanisms mediate proximal and distal motor activity of the colon.

Since the motor activity is only transiently reduced in the distal colon following spinal cord transection, poor compliance and absent postprandial motor and myoelectrical responses observed in man (Glick *et al.*, 1984, Meshkinpour

et al., 1983) are not likely to be associated with the change in the baseline state of colonic motor activity. It is understood that colon innervation in small mammals resembles that in man.

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Résumé

Dans cette étude, nous avons enregistré l'activité motrice du colon à l'état de repos, avant et immédiatement après la section transversale de la moelle chez des rats Sprague-Dawley du sexe male. Des électrodes ont été placés chirurgicalement dans le colon ascendant et descendant. Les variations de pression ont été enregistrées sur un dynographe utilisant un système de perfusion lente. Pour chaque session, un indice de motilité était préparé, prenant en considération l'amplitude, la durée et la fréquence des contractions. Suivant l'enregistrement de base, les animaux ont subi soit une section transversale de la moelle au niveau T_4, soit une opération factice. Les sessions d'enregistrement ont eu lieu tous les deux jours, pendant une période d'observation de trois semaines. Le premier jour post-opératoire, après la section transversale thoracique de la moelle, on nota une réduction sensible de l'indice de motilité du colon distal. Cependant, au bout de sept jours, l'activité motrice était retourneé graduellement au niveau pré-opératoire. L'opération factice n'eut aucun effet sur l'activité motrice.

Ces données suggèrent que l'activité motrice du colon chez les rats est influencée par un choc médullaire et aussi, probablement, par différent méchanismes nerveux controlant les activités proximales et distales du colon.

Zusammenfassung

Die hier beschriebene Untersuchung hat daher die Ruhemotorik des Dickdarms in Ratten mit experimentell geschädigtem Thorakalmark zum Gegenstand. Zu diesem Zweck wurden Sensoren chirurgisch im aufsteingenden und absteigendem Colon verankert. Druckschwankungen wurden mit Hilfe eines Dynographen registriert. Unter Berücksichtigung von Amplitude, Dauer und Häufigkeit der Kontraktionen wurde ein Motilitätsindex berechnet. Nach Kontrollbestimmungen wurde an den Ratten Transektion des Thorakalmarks bzw eine simulierte Operation durchgeführt. Registrierungen erfolgten in Intervallen von 48 Stunden. Transektion des Thorakalmarks führte am ersten postoperativen Tag zu einer merklichen Verringerung der Motilität. Dagegen war nach Ablauf einer Woche die Motilität wiederhergestellt. Nach den simulierten Operationen war keine Veränderung der Motilität zu beobachten. Aus diesen Beobachtungen ist zu schliessen dass die Motorik des Dickdarms durch einen vom Markschaden ausgelösten Schock beeinflusst werden kann, und dass wahrscheinlich für proximale und distale Funktion des Dickdarms verschiedene neurale Mechanismen vorliegen.

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