Differential Processing of Noxious Colonic Input by Thoracolumbar and Lumbosacral Dorsal Horn Neurons in the Rat

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Wang, Gexin, Bin Tang, and Richard J. Traub. Differential processing of noxious colonic input by thoracolumbar and lumbosacral dorsal horn neurons in the rat. J Neurophysiol 94: 3788–3794, 2005. First published August 10, 2005; doi:10.1152/jn.00230.2005. Previous studies suggest the lumbosacral (LS) spinal cord processes acute colorectal stimuli whereas the thoracolumbar (TL) and LS spinal segments process inflammatory stimuli. In this study, the effects of colorectal distention (CRD) on TL and LS dorsal horn neuronal activity were recorded in Nembutal-anesthetized male rats both with and without colonic inflammation. Both single cells (before and after inflammation) and populations (multiple cells from noninflamed or inflamed rats) were studied. CRD-responsive neurons had excitatory Abrupt (on–off with stimulus) or Sustained (prolonged after discharge) responses or were Inhibited by CRD. In noninflamed rats, a significantly greater percentage of LS neurons (63% Abrupt, 27% Sustained) were excited by CRD than TL neurons (61% Abrupt, 3% Sustained). The remaining cells were Inhibited (10% LS, 36% TL). LS Abrupt neurons had lower thresholds and greater response magnitudes to CRD compared with TL Abrupt neurons. After colonic inflammation, TL neurons became more excitable: the percentage of Inhibited neurons decreased, the response magnitude of Abrupt neurons increased, and the threshold decreased. In contrast, in single-cell recordings, the response of LS Sustained neurons increased, whereas LS Abrupt neurons decreased. These data suggest that in noninflamed rats, the net response to CRD of TL visceralceptive spinal sensory neurons is less than that of LS neurons. Colonic inflammation increases the net response of TL neurons and differentially modulates the response of LS neurons. These differences may contribute to the functional dichotomy between the TL and LS spinal segments in processing acute and inflammatory colorectal pain.

INTRODUCTION

A unique feature of the viscera is dual innervation by sensory afferent fibers projecting in the same nerves as sympathetic (splanchnic, hypogastric) and parasympathetic (vagal, pelvic) efferents. In the rat, the descending colon and rectum are innervated by primary afferent fibers projecting in the pelvic nerve to the L6–S2 spinal cord segments and hypogastric/lumbar colonic nerves projecting to the T13–L2 spinal cord (Mayer and Gebhart 1994; Mayer and Raybould 1990; Nadelhaft and Booth 1984; Ness and Gebhart 1988; Traub et al. 1999). However, the physiological role of this dual innervation in visceral nociceptive processing is unclear. Previous studies suggest that the lumbosacral (LS) and thoracolumbar (TL) spinal cord segments process acute and inflammatory pain from the colon and rectum differently. In humans, referred pain evoked by colorectal distention (CRD) in normal volunteers is perceived in the sacral dermatomes, whereas patients with irritable bowel syndrome or Crohn’s disease report referred pain expanding into the TL dermatomes (Bernstein et al. 1996). In rats, lesioning the hypogastric/lumbar colonic nerves did not affect avoidance behavior to noxious CRD (Ness et al. 1991). Conversely, L5–S3 dorsal rhizotomy eliminated the visceral-motor response (VMR), which partially recovered after colonic inflammation (Traub 2000). These data suggest that acute colorectal pain is processed in the lumbosacral spinal cord, recruiting the thoracolumbar spinal segments during pathophysiological conditions. Supporting data are provided by studies showing repetitive CRD induced Fos expression in LS spinal cord and minimal Fos in the TL spinal cord. After colonic inflammation, there was a significant upregulation of Fos expression in both regions of spinal cord (Traub and Murphy 2002).

The response of TL and LS dorsal horn neurons to CRD have previously been reported (Ness and Gebhart 1987, 1988, 1989). However, those studies were conducted in spinalized rats or in rats in which the cervical spinal cord was exposed. According to observations by Qin et al. (1999) stimulation of the C1 spinal segment suppresses activity of visceral nociceptive neurons in the lumbosacral spinal cord and noxious pinch in the head and neck region attenuates the response of LS neurons to CRD (Ness and Gebhart 1991). Therefore it is necessary to clarify how visceralceptive dorsal horn neurons process noxious or inflammatory stimuli from the colon under conditions where distal dermatomes remain intact. To address the hypothesis that the LS and TL spinal cord segments differentially process acute and inflammatory colorectal pain, we examined the response properties of TL and LS dorsal horn neurons to CRD in the absence and presence of colonic inflammation. Some of these data were presented in abstract form (Wang and Traub 2003).

METHODS

Animals and preparation

Experiments were performed in 80 adult male Sprague–Dawley rats weighing 270–380 g. All experimental procedures were approved by the University of Maryland Dental School Animal Care and Use committee and conform to the guidelines for use of experimental animals published by the International Association for the Study of Pain. Rats with or without colonic inflammation were prepared for recording from the thoracolumbar (T13–L2; TL) or lumbosacral (L6–S2; LS) spinal cord segments. Rats were deprived of food, but...
not water, for 18–24 h before the experiment. On the day of recording, rats were anesthetized with sodium pentobarbital (Nembutal, 50 mg/kg, administered intraperitoneally). The left carotid artery and left jugular vein were cannulated for monitoring arterial pressure and infusing anesthetic, respectively. Anesthesia was maintained by intravenous infusion of Nembutal (5–10 mg kg\(^{-1}\) h\(^{-1}\)). A catheter was inserted into the trachea for artificial ventilation. The wound margins were wiped with a local anesthetic ointment and sutured. The respiration rate was adjusted to maintain end tidal CO\(_2\) of 3.5–4.5% and a mean blood pressure of 100–130 mmHg. A thermostatically controlled water pad and overhead lamp were used to maintain body temperature. Experiments were terminated when either the mean blood pressure fell below 80 mmHg and/or the diameter of the pupil enlarged more than 2 mm for a period of time.

After being placed in a head holder, the rat was paralyzed with pancuronium bromide (0.2 mg kg\(^{-1}\) h\(^{-1}\)) and suspended with thoracic vertebral and iliac clamps. Laminectomies were performed in 48 rats to expose the L6–S2 spinal cord segments and in 28 rats to expose the T13–L2 segments. The dura matter of the exposed spinal segments was carefully removed. Skin flaps were used to form a pool that was filled with warm mineral oil.

### Electrophysiology

Tungsten microelectrodes (1–2 M\(_\Omega\), Micro Probe, Potomac, MD) were used for extracellular recording of single units in the L6–S2 or T13–L2 spinal segments from 0.5 to 1.5 (TL) or 1.2 mm (LS) lateral to the midline, 0.2–1.5 mm from spinal cord dorsum. The signal was amplified and fed into a window discriminator to isolate a single unit. The output of the discriminator was displayed on an oscilloscope and recorded to computer using a CED micro1401 with Spike2 software (Cambridge Electronics Design, Cambridge, UK) for on-line and off-line analysis. Units that responded to 80 mmHg CRD, whether excited or inhibited, were further studied.

### Colonic stimulation and inflammation

CRD was produced by inflating a balloon (made from the finger of a latex glove, 6–6.5 cm, attached to tygon tubing), which was inserted through the anus into the descending colon and rectum, to the desired pressure. The pressure was monitored and kept constant by a pressure-time device (Bioengineering, University of Iowa, Iowa City, IA). The search stimulus consisted of noxious (80 mmHg) CRD for 10 s, at a minimum of 1-min intervals and cutaneous stimulation (touch and light pinch) in the area of the presumptive receptive field. On finding a neuron responsive to 80 mmHg CRD, rats were distended with a series of graded-intensity stimuli. Each trial consisted of 20, 40, 60, and 80 mmHg distention, 20-s duration, at 3-min intervals. The cutaneous receptive field was mapped (see following text).

Twenty-nine rats were studied in the absence of colonic inflammation (noninflamed). In an additional 23 rats, the colon was inflamed by injection of mustard oil (2%, 0.25 ml) when the surgery was finished. Recordings were made between 30 min and 4 h after mustard oil injection. Multiple cells were studied in these rats (population study). In another 24 rats, the effects of colonic inflammation were observed in a single neuron (single-cell study). After recording two to three baseline trials, mustard oil (2%, 0.25 ml) was injected through a PE50 tube with holes on the side that was placed in the colon before recording. The responses to CRD were recorded 30, 60, and 90 min after mustard oil injection. At the conclusion of the experiment, an electrolytic lesion was made to mark the recording site. A block of tissue containing the lesion was immersion fixed. Sections (45 microns) were cut and stained with cresyl violet. The lesion was identified and drawn onto a standard picture of the LS or TL spinal cord.

### Data collection and analysis

Units were classified as Abrupt, Sustained, or Inhibited based on their response to 80 mmHg CRD (Ji and Traub 2002; Ness and Gebhart 1987). Abrupt neurons responded immediately at stimulus onset, rapidly reached the peak response, and rapidly (<5 s) returned to the baseline level at stimulus offset. Sustained neurons began responding at stimulus onset, reached a peak later during the stimulus (generally ≥10 s), and had a sustained afterdischarge at stimulus offset, decreasing to baseline between 5 and 140 s. Inhibited neurons were spontaneously active and were inhibited by CRD. Abrupt and Inhibited unit activity was quantified as the mean discharge frequency during the 20 s of the CRD stimulus minus spontaneous activity determined in the preceding 20 s. Sustained unit’s activity was measured as the mean discharge frequency during the 20-s distention plus the afterdischarge. The afterdischarge persisted until it dropped below the mean ± 2 SDs of the background activity (20 s before distention) for 2 s. The data are expressed as means ± SE. Data were analyzed in SigmaStat using \( \chi^2 \), t-test, paired t-test, two-way ANOVA, or two-way repeated-measures (RM) ANOVA as appropriate. Post hoc comparisons (Student–Newman–Keuls) were performed if the ANOVA term was significant. A value of \( P < 0.05 \) was considered significant.

### Somatic stimulation and the measurement of receptive field size

The size and location of the convergent cutaneous receptive field to noxious stimulation was determined with a blood vessel clamp. The boundary of the receptive field was determined by pinch and carefully mapped and drawn on a standard sketch of a rat and normalized as a percentage of the total area of the rat drawing. To do this the receptive fields were cut out of the sketches, weighed and normalized to the mean weight of 10 cutouts of the full sketch of the rat to determine the relative size (%) of the receptive field.

#### Evan’s Blue extraction

In 10 rats the extent of colonic inflammation was determined by quantifying the amount of Evan’s Blue extravasated into the colon. At the conclusion of the experiment, Evan’s Blue (50 mg/kg) was injected through the carotid cannula. After 15 min rats were overdosed with Nembutal and perfused with 200 ml normal saline. The colon was removed and placed in 5 ml dimethyl sulfoxide for 48 h. The concentration of extracted Evan’s Blue was detected by spectrophotometer at 620 nm \( \lambda \) absorbance and reported as micrograms Evan’s Blue per gram dry weight of colon. Nondistended rats were used to determine a baseline level of plasma extravasation.

### RESULTS

#### Evan’s Blue extraction

As a gauge of the magnitude of colonic inflammation, the amount of Evan’s Blue dye extravasated into the colon at the end of the experiment in 10 rats (four from noninflamed animals and six from inflamed animals) was determined. After colonic distention, there was 152 ± 32 \( \mu \)g Evan’s Blue/g colon (dry wt). Colonic inflammation with mustard oil significantly increased the Evan’s Blue extravasation to 1,119 ± 375 \( \mu \)g/g colon (t-test, \( P < 0.05 \)). In nondistended rats there was 60 ± 8 \( \mu \)g Evan’s Blue/g colon (n = 4).

#### Frequency distribution of TL and LS CRD responsive neurons and the effect of colonic inflammation

We recorded 133 neurons activated by CRD in the spinal dorsal horn: 68 in the TL spinal segments and 65 in the LS.
spinal segments. Thirty-six of the 68 TL neurons (13 rats) and 30 of the 65 LS neurons (16 rats) were recorded from rats in the absence of colonic inflammation (noninflamed rats). The remaining cells were recorded from rats with colonic inflammation (23 rats).

Neurons were classified into three groups on the basis of their response to 80 mmHg CRD: Abrupt, Sustained, and Inhibited (Fig. 1A). Neurons with similar response characteristics have been described previously (Al-Chaer et al. 1997; Ji and Traub 2002; Ji et al. 2003; Katter et al. 1996; Kolhekar and Gebhart 1996; Ness and Gebhart 1987; Olivar et al. 2000; Qin et al. 1999). In noninflamed animals these neurons were differentially distributed between the TL and LS spinal cord segments ($\chi^2, P < 0.005$, Fig. 1B). Of note is the absence of Sustained neurons and the large number of Inhibited neurons in the TL spinal cord. The mean depth of recorded neurons ranged from 812 to 1,226 $\mu$m from the cord dorsum (Fig. 2F), but there was no difference between groups.

After colonic inflammation there was still a differential distribution between TL and LS neurons ($\chi^2, P < 0.05$, Fig. 1B). In the LS spinal cord colonic inflammation evoked a decrease in the percentage of Abrupt neurons with a corresponding increase in Sustained neurons. There was no change in Inhibited neurons. In the TL segments, there was a small decrease in the percentage of Inhibited neurons, but there was no change in the percentage of Sustained neurons.

**Response properties and the effects of colonic inflammation**

The response threshold to CRD was lower in LS Abrupt neurons than that in TL Abrupt neurons as determined by the percentage of neurons that responded to 20 and 40 mmHg CRD (Fig. 2A). After colonic inflammation, the percentage of TL neurons that responded to 20 and 40 mmHg CRD increased (Fig. 2A), suggesting that inflammation decreased the threshold for response.

Examination of the response magnitude to graded intensities of CRD further illustrated differences between TL and LS neurons (Fig. 2B). In noninflamed rats, the magnitude of response of TL Abrupt neurons to graded intensities of CRD was significantly less than that of LS Abrupt neurons (two-way ANOVA, $P < 0.001$, Fig. 2B). There was no difference in the magnitude of inhibition (% change from background) of TL and LS Inhibited neurons (Fig. 2C). After colonic inflammation, the magnitude of response of TL Abrupt neurons significantly increased compared with neurons recorded in noninflamed rats (two-way ANOVA, $P < 0.001$; Fig. 2B). In contrast, colonic inflammation did not change the magnitude of response of LS Abrupt neurons (two-way ANOVA, $P = 0.649$). The magnitude of response to CRD of Inhibited neurons did not change in the TL or LS segments compared with noninflamed rats (Fig. 2C).

As shown in Fig. 1, there were too few Sustained neurons in the TL spinal cord to analyze, but there were sufficient neurons in the LS spinal cord. In the population study there was no effect of inflammation on the threshold or magnitude of response of LS Sustained neurons (Fig. 2, D and E), although there was an increase in the relative number of Sustained neurons in the LS spinal cord (Fig. 1B).

**The effect of colonic inflammation on individual TL and LS dorsal horn neurons**

Most published reports suggest that colonic inflammation increases the response of LS Abrupt dorsal horn neurons to CRD (Al-Chaer et al. 1997; Laird et al. 2001; Olivar et al. 2000). Although there is precedent that colonic inflammation does not increase the response of LS Abrupt neurons in spinalized rats (Ness and Gebhart 2000, 2001), the failure of inflammation to increase the response of LS Abrupt neurons in our experiments in intact rats warranted further investigation. Therefore the response of Abrupt and Sustained neurons was further examined by recording from cells in the TL and LS spinal segments of 24 rats before (baseline response) and 30, 60, and 90 min after colonic inflammation with mustard oil. In eight TL Abrupt neurons, the response to CRD increased in six neurons and did not change in two neurons. The mean response after colonic inflammation in the TL neurons significantly increased compared with the baseline response (two-way RM ANOVA, $P < 0.05$; Fig. 3, A and E). The increase was apparent by 30 min and maintained through 90 min (one-way RM ANOVA, $P = 0.006$; Fig. 3C). In contrast, the response of LS Abrupt neurons decreased in four neurons, increased in two neurons, and did not change in two neurons, resulting in a decrease in the mean response when compared with baseline (two-way RM ANOVA, $P < 0.05$; Fig. 3, B and E). Furthermore, the response of the LS neurons continually decreased compared with baseline over the recording period (one-way

**FIG. 1.** A: three characteristic response profiles of neurons responding to colorectal distention (CRD) in the lumbosacral (LS) and thoracolumbar (TL) spinal cord segments: Abrupt, Sustained, and Inhibited. For each pair of traces, the 1st trace shows the peristimulus time histogram (1-s bins) and the 2nd trace shows the extracellular recording. Duration of the CRD is shown as the bottom trace and is the same for the 3 examples. B: frequency distribution of neurons based on response patterns to CRD from noninflamed and inflamed rats. Number of neurons in each group is shown above the column.
RM ANOVA, P = 0.025; Fig. 3C). In both the TL and LS segments, Abrupt neurons did not acquire an afterdischarge following colonic inflammation.

In the LS spinal cord eight Sustained neurons were recorded before and after colonic inflammation. The response of six neurons increased and two did not change, resulting in a significant increase in the mean response (two-way RM ANOVA, P < 0.05) when compared with baseline (Fig. 3D). The discrepancy between the single-unit data and the population data can be attributed to the within-subject design of the single-unit study. Because the single-unit data compare individual cells before and after inflammation, they likely represent the true effect of colonic inflammation on visceroceptive dorsal horn neurons.

**Spontaneous activity and effects of colonic inflammation**

Eighteen of 22 (82%) TL and 16 of 19 (84%) LS Abrupt neurons had spontaneous activity in noninflamed rats. The mean rate of spontaneous activity of TL (8.8 ± 2.6 Hz) and LS Abrupt (10.1 ± 2.1 Hz) neurons and LS Sustained neurons (10.1 ± 2.3 Hz) were not different (Fig. 4A). Likewise, there was no difference in the mean rate of spontaneous activity between TL (24.4 ± 6.4 Hz) and LS (19.3 ± 3.2 Hz) Inhibited neurons (Fig. 4B).

Colonic inflammation increased the rate of spontaneous activity in TL Abrupt neurons (13.6 ± 2.2 Hz; t-test, P < 0.001; Fig. 4A). There was no change in the rate of spontaneous activity in LS Abrupt, Sustained, Inhibited, or TL Inhibited neurons.

**Response to somatic stimulation of visceroceptive TL and LS neurons and the effect of colonic inflammation**

The convergent cutaneous receptive field was examined in 106 cells from noninflamed and inflamed rats. Colonic inflammation did not change the somatic receptive field classification of CRD-responsive neurons. Between 75 and 95% of TL and LS excited neurons (Abrupt and Sustained) had NS- or WDR-type cutaneous receptive fields. In contrast, between 33 and
73% of Inhibited neurons had somatic receptive fields that were inhibited by pinch.

In 57 cells the size of the cutaneous receptive field that responded to pinch was mapped. Because we were trying to represent a three-dimensional structure on a standardized two-dimensional drawing of rats that differed slightly in size, simply determining the area of the receptive field on the drawing of the rat would be inaccurate. Therefore we normalized the size of the receptive field by determining the percentage of the area of the receptive field relative to the area of the entire rat. Before inflammation, there was no difference in the size of the receptive field between Abrupt and Sustained neurons in either the TL or LS spinal segments (Fig. 5). After colonic inflammation, the size of the receptive fields increased for the LS Abrupt and Sustained neurons and the TL Abrupt neurons (one-way ANOVA, $P < 0.001$ for LS and TL separately). The significant increase in the size of the convergent cutaneous receptive field after colonic inflammation is evidence for inflammation-induced central sensitization.

**DISCUSSION**

The present study describes the response properties of neurons that responded to CRD in the TL and LS spinal cord segments of neurologically intact rats in the absence and presence of colonic inflammation. Although spinal processing of visceral pain and noxious colorectal input in particular have been extensively studied in recent years, most studies focused on the response of LS dorsal horn neurons to colonic input (Al-Chaer et al. 1996, 1997; Berkley et al. 1993a; Ji and Traub 2001, 2002; Ji et al. 2003; Katter et al. 1996; Kolhekar and Gebhart 1996; Kozlowski et al. 2000; Ness and Gebhart 1987, 2000, 2001; Olivar et al. 2000; Qin et al. 1999). The few studies looking at TL neurons were conducted in spinally transected rats or in rats with the cervical spinal cord exposed for electrical stimulation (Ness and Gebhart 1988, 1989, 2000). Because the response of viscerosensitive dorsal horn neurons is inhibited by noxious stimulation of the head and neck (e.g., including cervical laminectomy) (Ness and Gebhart 1991) or descending bulbo-(cervical)-spinal activity (Qin et al. 1999; Tattersall et al. 1986; Zhang et al. 1996; Zhuo et al. 2002) the response of viscerosensitive dorsal horn neurons in rats without the confounding effects of an altered descending modulatory system is unclear.

**Response of TL and LS neurons to transient CRD and the effects of colonic inflammation**

Our group has hypothesized that the TL and LS spinal segments differentially contribute to processing acute and in-
flamatory colorectal stimuli and the present results support this hypothesis. The TL spinal cord appears less excited by CRD than the LS spinal cord in the absence of colorectal inflammation and inflammation increases the level of excitability of the TL spinal cord. This conclusion is based on the following lines of evidence. First, in noninflamed rats four times as many CRD-responsive neurons were inhibited in the TL spinal segments compared with the LS segments and colorectal inflammation decreased the percentage of TL inhibited neurons. Second, the threshold for activating TL neurons was greater than that of LS neurons, but decreased during inflammation. Third, the magnitude of the response to CRD was significantly greater in LS neurons than that in TL neurons. Colonic inflammation increased the response of TL Abrupt neurons, but had a tendency to decrease the response of LS Abrupt neurons. However, inflammation increased the number and magnitude of response of LS Sustained neurons. This increase in the relative number of Sustained neurons in the LS spinal cord of inflamed rats, combined with the observations that inflammation does not induce Abrupt neurons to develop an afterdischarge and colonic inflammation increases the number of CRD-induced Fos labeled cells in the dorsal horn (Traub and Murphy 2002), suggests that increasing the number of neurons that respond to CRD may be as important to developing hyperalgesia as increasing the response of individual dorsal horn neurons. Furthermore, the overall increase in the level of activity of the TL spinal cord combined with the fact that LS dorsal rhizotomy attenuates the CRD-evoked vmr, which is partially reversed during colorectal inflammation (Traub 2000), support an enhanced role for the TL spinal segments in processing inflammatory pain.

Discrepancies with the literature

Our results differ from previous work in a number of ways, although all differences can be attributed to experimental design. We found <5% of the TL neurons had sustained afterdischarges with or without mustard oil-induced colorectal inflammation. In contrast, Ness (Ness and Gebhart 1988) reported that 42% of the TL neurons from noninflamed rats had a sustained afterdischarge. In addition they reported that TL and LS Abrupt neurons had similar responses to CRD in contrast to the present results. The likely reason for these differences was that Ness mostly used spinalized rats. Neurons recorded from spinally intact rats had smaller responses. In preliminary studies we observed that cold block causes Abrupt neurons to develop an afterdischarge similar to that of Sustained neurons. Furthermore, abdominal surgery increases the percentage of Sustained neurons in the TL spinal cord segments (Wang and Traub 2004). These data suggest that acute surgery and/or spinalization sufficiently alters neuronal responses to CRD such that data from spinalized and intact preparations are not directly comparable.

Conclusions about the response of different groups of dorsal horn neurons to colorectal inflammation may also depend on the experimental design. Although we reported the response of LS Abrupt neurons decrease after inflammation, the opposite result has also been reported (Al-Chaer et al. 1997; Ji et al. 2005; Olivar et al. 2000). Again, experimental design likely contributes to the differences. Our study did not target a particular subset of spinal dorsal horn neurons such as neurons with supraspinal projections in the dorsal columns (Al-Chaer et al. 1997). More interestingly, our study was done in male rats. In contrast, in intact or hormonally modulated female rats the response of Abrupt neurons was facilitated after colonic inflammation and Sustained neurons were not affected (Ji et al. 2005; Olivar et al. 2000). Taken together, these data suggest that spinal neurons responding to visceral stimuli are subject to multiple factors that rigorously influence response characteristics.

Colonic afferent contribution to differential processing of CRD

Although the present data suggest that spinal mechanisms contribute to the differences in excitability of TL and LS dorsal horn neurons to CRD, differences in the properties of colonic primary afferents projecting to the two regions of spinal cord cannot be excluded. The majority of colonic afferents in the rat pelvic nerve in vivo are low threshold fibers that encode stimulus intensity up to 100 mmHg and are sensitized after colonic inflammation (Berkley et al. 1993b; Sengupta and Gebhart 1994; Su et al. 1997). Thoracolumbar colonic afferents in the rat are less well studied (Lin and Al-Chaer 2003). In contrast, feline pelvic nerve (LS) colonic afferents have slightly lower thresholds than those of lumbar splanchnic nerve (TL) colonic afferents, although the stimulus-response functions for these afferents were similar (Blumberg et al. 1983; Janig and Koltzenburg 1991).

In vitro studies from mouse and rat isolated colon–nerve preparations reported splanchnic nerve afferents had higher thresholds than those of pelvic nerve afferents (Brierley et al. 2004; Lynn and Blackshaw 1999). Likewise, the threshold and rheobase recorded from dissociated TL colonic afferent DRG cell bodies were higher than those of LS DRG cell bodies, although the suprathreshold response of TL cells was greater than that of LS cells (Gold and Traub 2004). Although it is difficult to compare punctate stimulation of the isolated, opened colon in vitro to colorectal distention in vivo and determine what are comparable stimuli, or relate membrane properties in vitro to distention thresholds and stimulus-response functions in vivo, the data support lower thresholds, but...
are equivocal regarding suprathreshold responses by LS versus TL colonic afferents. Therefore, while some of the present observations can probably be attributed to differences in primary afferent input to the spinal cord, peripheral mechanisms cannot account for all the differences in spinal processing of CRD between TL and LS spinal segments.

In conclusion, these results demonstrate a difference between the response of the thoracolumbar and lumbosacral spinal cord segments to acute and inflammatory colorectal pain. The neurons responding to CRD in TL segments show less activity compared to those in the LS segment, in terms of the mean magnitude of response, response threshold, and the percentage of excited neurons. The decrease in relative percentage of inhibited neurons and the increase in the response of excited neurons in the thoracolumbar spinal cord after colonic inflammation supports the hypothesis of a differential role for these two regions of spinal cord in processing colorectal pain and hyperalgesia.

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