EFFECTS OF SEGMENTAL THORACIC EXTRADURAL ANALGESIA ON SYMPATHETIC BLOCK IN CONSCIOUS DOGS

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A study [1] based on temperature measurements has suggested that the extent of sympathetic block after spinal anaesthesia is greater than assumed previously and this has renewed interest in this area [2]. Based on loss of cold sensation, the traditional view is that the rostral level of sympathetic block extends two or more segments above the level of insensitivity to pinprick stimulation with spinal [3], but not with extradural anaesthesia [4]. This concept is based on the assumption that cold afferent fibres have a diameter and sensitivity to local anaesthetics similar to those of sympathetic efferent fibres so that the dermatomes with loss of cold sensation should be consistent with the area of sympathetic block [1, 3].

In this study we have examined the spread of sympathetic block with segmental extradural anaesthesia by multiple temperature measurements. Changes in skin temperature can reflect only changes in skin blood flow, and thus sympathetic tone, when both ambient and body temperature are constant [5]—conditions not achieved easily in an operating room. This and ethical constraints against human volunteer studies led us to assess the effects of segmental extradural block at upper thoracic, mid thoracic and lumbar levels under conditions of constant environmental temperature in trained conscious dogs.

MATERIALS AND METHODS

Investigations were carried out in six trained short fur dogs (German boxers; weight 19–25 kg)

SUMMARY

To test the hypothesis that segmental thoracic extradural block causes sympathetic denervation caudally beyond dermatomes rendered analgesic, we have measured regional skin temperatures in six conscious dogs after upper thoracic, mid thoracic, and lumbar extradural injection of 0.5% bupivacaine 0.5, 1 and 2 ml cumulatively (total dose: 3.5 ml) given at 45-min intervals. Dogs were studied at constant ambient and rectal temperatures. Upper thoracic extradural injections resulted in a significant increase in skin temperatures on both the front (+1.4 (SEM 0.2) °C) and hind paw (+1.4 (0.3) °C), while the area of analgesia was confined to the upper trunk. With lumbar extradural injection, skin temperatures increased significantly (+2.0 (0.5) °C) on the lower extremities only. Mid thoracic injection significantly increased both front (+2.4 (0.9) °C) and hind paw (+2.2 (0.6) °C) skin temperatures, but decreased temperatures on the thorax (−0.9 (0.2) °C) and abdomen (−1.0 (0.2) °C), reversing the normal temperature gradient along the body axis. Irrespective of the injection site, skin temperatures on the trunk failed to increase or even decreased significantly. These data suggest that small doses of local anaesthetics applied to the extradural space of conscious dogs cause increased lower extremity skin temperatures caudal to areas unresponsive to pinprick stimulation when injected at a high thoracic level, and decreased trunk skin temperature even in analgesic areas, so that skin temperature measurements are unlikely to reflect purely sympathetic efferent activity on the trunk. Upper thoracic segmental extradural analgesia induced a decrease in sympathetic tone distal to the area of analgesia.
housed in the local animal care facility. Four of the animals had one or both common carotid arteries exteriorized in skin loops several months before the study for measurement of arterial pressure. The effects of extradural anaesthesia were assessed at constant ambient temperature of approximately 21 °C, that is, less than the thermo-neutral range, which is 24 °C in dogs [6, 7].

Skin temperatures were measured in the same skin area at eight different body regions (dorsal front paw \(T_1\), front limb \(T_2\), shoulder \(T_3\), thorax overlying the 4th rib \(T_4\), abdomen \(T_5\), seat \(T_6\), hind limb \(T_7\), and dorsal hind paw \(T_8\)) with sensors of our own design [8], and recorded with rectal and ambient temperatures. Arterial pressure was measured (Statham 23 ID transducer) via a catheter inserted into a carotid loop (four dogs) or femoral artery (two dogs) and heart rate by an ECG triggered cardiotachometer. Signals were recorded continuously on a Beckman polygraph.

One to two days before each experiment, a radiopaque wire-reinforced catheter was inserted through a 16-gauge Tuohy needle into a lumbar intervertebral space (usually L5/L6) under sterile conditions during anaesthesia with methohexitone 4 mg kg\(^{-1}\) i.v. It was advanced to the level of the first thoracic interspace using fluoroscopy, sutured to the skin, and secured with plaster of Paris. Subsequently, the effects of extradural anaesthesia were studied on different days in each dog in the conscious state with the catheter tip placed at vertebral bodies T1 or T2 (Series I: upper thoracic block), T8 (Series II: mid thoracic block), or L4 (Series III: lumbar block). The respective catheter positions were achieved by withdrawing the catheter from its initial upper thoracic position under fluoroscopy. At least 2 days elapsed between experiments.

All dogs, trained to lie unrestrained on their right side during the experiments, were studied in the morning after an overnight fast. Ambient temperature was maintained within ±0.4 °C and did not differ between studies. No drugs or fluids were given at any time. With all catheters and temperature sensors in place, 60 min was allowed to elapse before measurements. After a further control period of 15 min to ensure a stable baseline, incremental volumes (0.5, 1 and 2 ml; cumulative dose 3.5 ml) of 0.5% bupivacaine (stored at room temperature) were injected into the extradural space at 45-min intervals in each experiment. Analgesia was assessed by the dogs' behavioural responses (head rising, withdrawal) to pinprick.

In preliminary experiments the effects of extradural injection of saline up to 10 ml stored at room temperature, or of deep i.m. injection of bupivacaine 10 ml were studied to exclude effects secondary to a potentially changed spinal cord temperature or increased blood concentrations of local anaesthetic. No appreciable effect was noted. Arterial blood-gas analysis in four dogs revealed that extradural block produced no changes in \(P_{\text{a}O_2}\), \(P_{\text{a}CO_2}\) or pH.

Data are reported as means (SEM). As full nerve block was established within 30–45 min with changes in skin temperature reaching a plateau, differences in variables between control and denervated states immediately before injection of the next dose of bupivacaine (45 min after each injection) were evaluated by analysis of variance for repeated measurements (ANOVA) for each series. When significant differences were detected, variables were analysed further using Scheffe's test [9]. Statistical significance was assumed at \(P < 0.05\).

**RESULTS**

The effects of extradural bupivacaine on skin temperature depended on time after injection, site and volume injected, and on the skin region evaluated. The time course is shown in figure 1 for mid thoracic injections at T8. Skin temperature increased on both the front \(T_1\) and hind paws \(T_8\), but decreased on the thorax \(T_4\). The temperature increase on the front paw (+1.4 (0.2) °C) was the same as on the hind paw (+1.4 (0.3) °C). Despite the increase in lower extremity temperature, unresponsiveness to pinprick was confined caudally to dermatomal levels as high as T3—that is, the area of skin temperature increase extended caudally well beyond the area of analgesia into dermatomes where the response to pinprick stimulation was preserved. The caudal dermatome rendered analgesic ranged from T3 to
Fig. 1. Time course of changes in regional skin temperatures from baseline at selected body sites with mid thoracic extradural injection of 0.5% bupivacaine in incremental doses at 45-min intervals (mean (SEM)) from six dogs. The temperature changes on the front ($T_1 = •$) and hind paw ($T_8 = •$) are compared with those on the abdomen ($T_5 = •$). After injection of bupivacaine 0.5 ml, skin temperatures increased on the extremities, but decreased on the abdomen. As changes in skin temperature appeared to plateau 30-45 min after each injection, variables were evaluated statistically 45 min following each injection. Compared with baseline, all temperature changes were significant after the second (1-ml) and third (2-ml) injections.

T12 (Table I). Sensory and motor innervation remained intact on both the upper and lower extremities. Although less pronounced, the same trend in skin temperatures was observed after a total injection of 1.5 ml, whereas injection of 0.5 ml had little effect on skin temperatures and response to pinprick stimulation.

**Series II**

With mid thoracic extradural anaesthesia, temperatures increased significantly on the limbs and decreased on the trunk (fig. 2). With a volume of 0.5 ml of bupivacaine, temperatures tended to increase on both the front and hind limbs, but

**Table I. Dermatomal spread of sensory block with segmental extradural anaesthesia in six conscious dogs.**
The most caudal dermatome with high thoracic and the most cranial dermatome with lumbar injection unresponsive to pinprick stimulation are shown for individual dogs. Data refer to injections of a cumulative dose of 0.5% bupivacaine 1.5 (0.5+1.0) ml and 3.5 (0.5+1.0+2.0) ml. As dogs had no appreciable analgesia with injection of 0.5 ml, data are not shown. NA = No reliable segmental assessment of analgesia was possible.

<table>
<thead>
<tr>
<th>Dog No.</th>
<th>Upper thoracic injection (Lowest analgesic dermatome)</th>
<th>Lumbar injection (Highest analgesic dermatome)</th>
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<tr>
<td></td>
<td>1.5 ml</td>
<td>3.5 ml</td>
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<tr>
<td>1</td>
<td>No analgesia</td>
<td>T3</td>
</tr>
<tr>
<td>2</td>
<td>T2</td>
<td>T3</td>
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<tr>
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<tr>
<td>4</td>
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<td>T12</td>
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decreased on the thorax and abdomen, with a transitional zone on the shoulder and seat. These changes were significant with the second and third injections of bupivacaine. For absolute skin temperatures (table II), the normal temperature gradient alone the body axis (with the highest temperatures on the chest and the lowest on the paws) was inverted after mid thoracic extradural block. Sensory and motor function remained intact on the upper extremity with a cumulative dose of 3.5 ml, but on the hind limbs only in some animals. The increase in both upper and lower temperatures was observed also in those dogs in which analgesia was limited to a girdle shaped area involving only the lower chest and upper abdominal areas—that is, again, the area of

Fig. 2. Changes from baseline in regional skin temperature along the body axis with upper thoracic (T1), mid thoracic (T8) and lumbar (L4) extradural injections of 0.5 % bupivacaine in incremental doses of 0.5 ml (open columns), 1.0 ml (striped columns), and 2.0 ml (black columns) at 45-min intervals (mean (SEM)) from six dogs. With both upper and mid thoracic block, regional skin temperatures increased on the upper and lower extremities, but decreased on the trunk. With lumbar injection the temperature profile differed clearly from that with thoracic injection, since the increase in skin temperature was confined to the lower extremity. Regardless of the injection site, skin temperatures failed to increase or even decreased significantly on the trunk. T1 = Dorsal front paw; T2 = front limb; T3 = shoulder; T4 = thorax; T5 = abdomen; T6 = seat; T7 = hind limb; T8 = dorsal hind paw.
increased skin temperatures extended both cranially and caudally beyond analgesic dermatomes.

**Series III**

With lumbar extradural injection of bupivacaine, skin temperatures increased only on the lower extremities, but decreased on the upper extremities and trunk (fig. 2). With the last injection of bupivacaine, skin temperatures increased significantly on both the hind limb (+1.2 (0.3) °C) and hind paw (+2.0 (0.5) °C), but decreased significantly on the thorax (−0.6 (0.2) °C). All dogs maintained normal responsiveness to pinprick on the upper extremity and upper trunk (table I).

Regional skin (table II), ambient and rectal temperatures at baseline were not different between the series. Rectal temperatures remained unchanged during the experiments in all series. In spite of a uniform decrease in trunk skin temperature, regardless of injection site, arterial pressure decreased significantly, by 18 mm Hg, only with the last injection of bupivacaine at the mid thoracic level (fig. 3). Heart rate did not change significantly in either group.

**DISCUSSION**

The loss of sympathetic tone during extradural block was more widespread than expected, and the level of sympathetic block exceeded that of sensory block by several segments both cranially and, remarkably, also caudally to the analgesic dermatomes.

This conclusion is based on the assumption that changes in skin temperature reflect changes in sympathetic tone. In general, there are parallel changes between sympathetic activity, blood flow and skin temperature. For nerve blocks, vasodilation causes skin temperature increases in the denervated limbs and this reflects loss of sympathetic tone, provided that ambient temperature is constant and close to or below the thermoneutral temperature range [10, 11]. In man, toe, finger and hand (mainly skin) blood flow increase linearly as skin temperature increases from 24 to 35 °C [10–13].

The relationship between sympathetic drive and skin temperature on the trunk is less clear, mainly because reliable techniques for measurement of blood flow are not available and temperature changes are small and inconsistent. Unlike the limbs, skin temperature does not increase and often decreases during spinal anaesthesia in man [14, 15] and extradural anaesthesia in dogs [8]. Cutaneous erythrocyte velocity (laser Doppler) (not necessarily skin blood flow) decreased slightly with the reduction in skin temperature in (sensory) denervated dermatomes on the trunk in the majority of cases after spinal anaesthesia [14, 15]. With some reservations regarding the trunk, it is justified, therefore, to view the increase in skin temperatures on the limbs as loss of sympathetic tone under the conditions of our experiments (constant ambient temperature slightly below the thermoneutral range, constant rectal temperature, absence of sweating (dogs have no sweat glands except under the paws [6, 16]) and a skin temperature range of 28–33 °C). We cannot state, however, whether the increased limb temperatures reflect complete or partial sympathetic block.

The extent of sympathetic block with extradural anaesthesia especially in the caudal direction,
REGIONAL SKIN TEMPERATURE AND EXTRADURAL BLOCK

Fig. 3. Mean (SEM) changes in mean arterial pressure (MAP), and heart rate (HR) from baseline after incremental extradural injection of 0.5% bupivacaine 0.5 ml (open columns), 1 ml (striped columns), and 2.0 ml (black columns) given at 45-min intervals. Injections were performed at upper thoracic (T1), mid thoracic (T8) and lumbar (L4) extradural sites. Data from six dogs 45 min after injection of each dose. Compared with baseline, only mid thoracic injection at the largest dose resulted in a significant decrease in mean arterial pressure (* P < 0.05).

exceeded the borders of analgesia and thus was more widespread than thought previously. Other investigators, using loss of cold sensation, concluded that in the cranial direction sympathetic block extended only one, if any, dermatome above the level of sensory block following lumbar extradural injection [4].

There are several possible explanations for the extensive caudal spread of sympathetic block observed in our study.

Preferential spread of local anaesthetic within the extradural space itself is unlikely to account for the observed differential effect of high thoracic vs. lumbar injection on limb skin temperatures, as no preferential rostral or caudal spread was demonstrated with radiological or radionuclide methods in either man or dog [16-19]. Injection of 3 ml of radiopaque contrast media into the extradural space at the C7-T1 space in dogs (that is, only one space rostral to the injection site for upper thoracic block in our study) resulted in equal spread of approximately three segments in both the rostral and caudal directions [17].

Preganglionic sympathetic fibres ascend and descend in the paravertebral sympathetic chain before synapsing with postganglionic neurones both above and below their segmental points of origin [2, 20, 21]. Those supplying the hind limbs could have emerged from the spinal cord at a much higher level than the sensory nerves of the lower extremity enter it, resulting in segmental analgesia restricted to only the upper thorax, but also in widespread sympathetic block involving the hind limbs with high thoracic extradural injection.

In addition to nerve blocking effects exerted in the extradural and paravertebral spaces, extradurally applied local anaesthetics can also penetrate the cord [22] and block descending supraspinal pathways, as indicated by Babinski's sign during thoracic block [23]. Descending supraspinal sympathetic pathways, which are assumed to be tonically active [24], are found in the superficial aspect of the anterolateral column in many species, including man [25]. Thus block of these pathways could explain diminished sympathetic outflow to the hind limbs too.

Current studies in our institution have also demonstrated, in man, increased toe temperatures with high segmental thoracic extradural anaesthesia, despite a caudal border of sensory block limited to T6. Also, a 32% mean increase in foot blood flow has been reported in patients with mid thoracic block and a mean segmental spread from T2 to T12 [26].

In this study, trunk skin temperatures decreased even in analgesic dermatomes. In a previous study [8] we found decreased trunk skin temperatures also with complete extradural sympathetic block, indicating that a compensatory increase in sympathetic drive from unblocked spinal segments alone (for example because of baroreflex activation [27]) is unlikely to be responsible. The decrease in trunk skin temperatures at constant ambient and rectal temperatures implies a reduction in skin blood flow, by either active or passive mechanisms, that masks vasodilating effects of sympathetic block. The observations that arterial pressure did not decrease significantly, except with the largest mid thoracic injection, and that a decrease in trunk skin temperature occurred in all groups, suggest that a direct perfusion pressure dependent effect was unlikely. Possible mechanisms for the temperature decrease include flow redistribution to the limbs or net vasoconstriction on the trunk, possibly by vasopressin, the concentration of which increases in response to sympathetic block [28]. While changes in trunk
skin temperature with extradural anaesthesia have not been evaluated in man, both decreases [14, 15] and increases [1] were found with spinal anaesthesia. Whatever the reasons for the conflicting results, the body of evidence suggests that, in contrast with limbs, caution is indicated in the interpretation of fluctuations in skin temperature on the trunk in terms of changed sympathetic activity after nerve block.

REFERENCES
12. Spealman CR. Effect of ambient air temperature and of