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SUMMARY The autoregulatory capability of regional areas of the brain and spinal cord was demonstrated in 18 rats anesthetized with a continuous infusion of intravenous pentothal. Blood flow was measured by the injection of radioactive microspheres (Co⁵⁷, Sn¹¹⁳, Ru¹⁰³, Sc⁴⁰). Blood flow measurements were made at varying levels of mean arterial pressure (MAP) which was altered by neosynephrine to raise MAP or trimethaphan to lower MAP. Autoregulation of the spinal cord mirrored that of the brain, with an autoregulatory range of 60 to 120 mm Hg for both tissues. Within this range, cerebral blood flow (CBF) was 59.2 ± 3.2 ml/100 g/min (SEM) and spinal cord blood flow (SCBF) was 61.1 ± 3.6. There was no significant difference in CBF and SCBF in the autoregulatory range. Autoregulation was also demonstrated regionally in the left cortex, right cortex, brainstem, thalamus, cerebellum, hippocampus and cervical, thoracic and lumbar cord. This data provides a coherent reference point in establishing autoregulatory curves under barbiturate anesthesia. Further investigation of the effects of other anesthetic agents on autoregulation of the spinal cord is needed. It is possible that intraspinal cord compliance, like intracranial compliance, might be adversely affected by the effects of anesthetics on autoregulation.

Methods

Eighteen adult Sprague Dawley rats (450–555 g) were anesthetized with intraperitoneal pentobarbital (75 mg/kg). The animals were intubated and ventilated with air and oxygen to maintain PaO₂ (greater than 60 mm Hg) and PaCO₂ (33–44 mm Hg) within normal physiologic limits. ECG was monitored continuously and temperature (measured rectally) was maintained with warming lights. An incision was made in the left groin and a femoral artery catheter was inserted to monitor arterial blood pressure and for the sampling of arterial blood. A femoral vein catheter was inserted for drug administration. An incision was then made in the neck and a catheter was inserted into the left ventricle via the right carotid artery. Placement was confirmed by observation of the left ventricular pressure pattern. The ventricular catheter was used for microsphere injections in order to measure blood flows. A catheter was also inserted into the left jugular vein and advanced into the superior vena cava for measurement of central venous pressure. An additional dose of intraperitoneal pentobarbital, 25 mg/kg was given during line insertion. After completion of line insertion, the animals were paralyzed with pancuronium bromide 0.1 mg/kg/hr and maintained on a continuous intravenous infusion of pentothal (250 mg of pentothal mixed in 250 ml of normal saline) at a rate of 4 mg/kg/hr.

Blood flow measurements were then made in each animal at varying levels of mean arterial pressure vascular dynamics. However, a comparison between the autoregulatory capabilities of these two tissues has not been demonstrated.

The purpose of this study was to simultaneously measure spinal cord and cerebral blood flow under conditions of varying mean arterial blood pressure and to determine if this parallelism, indeed does exist. Autoregulatory capabilities of regional areas of the brain and spinal cord will also be determined.
Highly concentrated solutions of neosynephrine and trimethaphan received both neosynephrine and trimethaphan. The microspheres used for measurement of blood flow were of 15 ± 5 μm diameter and labeled with four gamma-emitting isotopes (57Co, 113Sn, 103Ru, 44Sc). Approximately 0.3 ml of microsphere solution (500,000 microspheres per ml) was injected into the left ventricle and immediately flushed with 0.3 ml of saline. Reference arterial blood samples were withdrawn from a catheter in the femoral artery beginning immediately prior to injecting and continuing for 1 minute after initiation of the injection. The order of isotope injection was randomized for each animal.

After completion of the microsphere injections, the animals were sacrificed with intravenous KCL. The brain and spinal cord were removed and the following sections dissected by anatomical landmarks: left cortex, right cortex, cerebellum, hippocampus, thalamus, brainstem, cervical, thoracic, and lumbar spinal cord. Radioactivity of the tissue and reference blood samples were measured by counting for 1 minute on a Packard® multichannel AutoGamma Scintillation Spectrometer. Blood flows were obtained by computer calculation (as has been previously described), using the following formula:

\[ F = \frac{CT}{CB} \times 100 \]

where:
- \( F \) = tissue blood flow (ml/100 g/min)
- \( CT \) = counts/gram of tissue
- \( CB \) = counts/ml/minute of reference arterial blood.

Data was then plotted against perfusion pressure for the total cerebral and spinal cord flows and for each of the individual sections. A best fit curve obtained by polynomial regression analysis was drawn through the data with calculation of a correlation coefficient and an F-ratio statistic for evaluation of statistical significance of the relationship between blood flow and perfusion pressure. Significance was taken to be \( p < .05 \). Curves for each brain and cord section were based on analysis of 51 blood flow measurements.

Within the autoregulatory range established by the best fit curves, the mean brain and mean spinal cord flows were compared. Flows in the autoregulatory range of each of the individual brain and cord sections were also compared. Data comparisons were made using a two-way analysis of variance followed by a student Neuman-Keuls (normal data) or Friedman’s test (nonnormal data). Significance was again taken to be \( p < .05 \).

### Results

Arterial blood gases remained within normal physiological limits. Mean PaCO₂ was 38.02 ± 2.6 (SD) and mean ph was 7.35 ± .05. Mean PaO₂ was 135.0 ± 27.1.

Average brain blood flow was determined by pooling data from the individual brain sections. Cerebral blood flow (CBF) remained relatively constant within the range of 60 to 120 mm Hg at 59.2 ± 3.2 (SEM) ml/100 g/min. Above 120 mm Hg, increases in CBF paralleled increases in perfusion pressure (PP) to a maximum flow of 214 ml/100 g/min at the highest PP measured (187 mm Hg). Below 60 mm Hg, changes in CBF also paralleled reductions in PP to a minimum flow of 5.0 ml/100 g/min at a PP of 30 mm Hg.

Average spinal cord blood flow was determined by pooling data from the three cord sections. Spinal cord blood flow (SCBF) remained relatively constant within the range of 60 to 120 mm Hg at 61.1 ± 3.6 ml/100 g/min. Above 120 mm Hg, SCBF increased with further increases in PP to a maximum flow of 229 ml/100 g/min at a PP of 187 mm Hg. Below 60 mm Hg, SCBF decreased with further lowering in PP to a minimum flow of 3 ml/100 g/min at a PP of 30 mm Hg.

A graphic comparison of the established autoregulatory curves for the brain and spinal cord was made. These curves appear to be virtually identical (fig. 1). Individual autoregulatory curves for each of the brain and cord sections were established (figs. 2 and 3). Left cortical blood flow remained relatively constant within the range of 60 to 120 mm Hg. Blood flow in this range of PP was 54.2 ± 3.8 ml/100 g/min.

Right cortical blood flow was also relatively constant throughout the same range and the mean blood flow in this range was 45.1 ± 3.3 ml/100 g/min.

Brainstem, thalamic, cerebellar, and hippocampal blood flows also did not appear to vary over the range of 60 to 120 mm Hg. Mean blood flows in this range were 67.7 ± 3.3, 56.5 ± 4.8, 80.1 ± 4.9, and 51.0 ± 4.0 ml/100 g/min respectively.

Cervical, thoracic and lumbar blood flow also did...
FIGURE 2. The left cortex, right cortex, brainstem, cerebellum, thalamus and hippocampus all demonstrated similar autoregulatory patterns. Best fit curves have been obtained by polynomial regression analysis of the individual data points.

not vary significantly within the range of 60 to 120 mm Hg. Blood flows in this range of PP were 43.7 ± 4.8, 35.3 ± 3.1 and 56.4 ± 3.7 ml/100 g/min respectively.

No significant difference was demonstrated between the mean brain and spinal cord blood flows in the autoregulatory range. Left cortical blood flow was higher than right cortical blood flow in the autoregulatory range (p < .05). Cerebellar blood flow appears to be higher than any of the other brain regions at a significance level of p < .01. Brainstem blood flow in the autoregulatory range was higher than each of the brain regions except the cerebellum (p < .05). Analysis of individual cord flows demonstrated that lumbar flow was higher than thoracic flow (p < .01) and cervical flow (p < .05).

A summary of regional blood flows in the autoregulatory range is presented in table 1.

Discussion

Although autoregulation has been extensively investigated in the cerebral vasculature, considerably less information is available on autoregulation of spinal cord blood flow. This may be, in part, due to limitations in the methodology of blood flow measurement. Some of the techniques traditionally used to measure cerebral blood flow are unsuitable for the spinal cord. The Kety-Schmidt inhalation technique is based on measuring the mean transit time for tracer molecules to traverse the brain by analysis of systemic arterial and cerebral venous blood. This technique is unsuitable for measurement of spinal cord blood flow because of the difficulty in obtaining representative venous blood samples. The Lassen-Ingvar method of monitoring the brain washout of a radioactive inert gas following its bolus injection into the carotid artery is also unsuitable because it is not possible to obtain selective labeling and recording of the cord. As a result of the limitations of these methods, many investigators have used diffusible indicators or hydrogen clearance techniques to estimate spinal cord blood flow. Autoradiographic analysis of tissue distribution of diffusible indicators (14C-antipyrine or CF3I) has the disadvantage that only a single measurement of blood flow can be made in the same animal. The hydrogen clearance technique involves the insertion of platinum electrodes into the cord to measure the rate of washout of inhaled hydrogen gas. This method is disadvantageous in that it requires invasion of the spinal canal. It has also yielded lower values for spinal cord blood flow than other techniques. Other methods used have included the use of a surface flow device which permits the measurement of qualitative blood flow changes only and Xenon washout, which necessitates a direct injection of 133Xe into the parenchyma of the spinal cord, and may increase the possibility of cord damage with multiple flow determinations.

A more recent method of measuring spinal cord blood flow is the microsphere technique. Labeled microspheres are injected into the left ventricle of experimental animals to enable complete mixing with arterial blood. The microspheres distribute throughout the body and are trapped in the microcirculation, being too large to pass through the capillary bed. Their distribution to the organs of the body is in direct proportion to their blood flow. Microspheres labelled with different gamma emitting isotopes can be separated with differential spectroscopy. Although this technique does not readily differentiate white and gray matter flow, it does have the advantage of allowing repeated measurements of blood flow in the same animal, is neurologically noninvasive, and permits measurement of regional blood flows.

Using the microsphere technique, our values for

![Autoregulation of Spinal Cord Blood Flow](image)

FIGURE 3. Autoregulatory curves for the cervical, thoracic and lumbar spinal cord have been obtained by polynomial regression analysis of the individual blood flows.
TABLE 1  Autoregulation of CNS Blood Flow

<table>
<thead>
<tr>
<th>Region</th>
<th>Autoregulation Range (PP in mm Hg)</th>
<th>Autoregulation Range (PP in mm Hg)</th>
<th>Autoregulation Range (PP in mm Hg)</th>
<th>Autoregulation Range (PP in mm Hg)</th>
<th>Blood Flow (ml/100 g/min) values given as mean ± SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>59.2 ± 3.2</td>
</tr>
<tr>
<td>Spinal cord (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>61.1 ± 3.6</td>
</tr>
<tr>
<td>Left cortex (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>54.2 ± 3.8*</td>
</tr>
<tr>
<td>Right cortex (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>45.1 ± 3.3*</td>
</tr>
<tr>
<td>Brainstem (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>67.7±3.3†</td>
</tr>
<tr>
<td>Thalamus (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>56.5 ± 4.8</td>
</tr>
<tr>
<td>Cerebellum (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>80.1 ± 4.9‡</td>
</tr>
<tr>
<td>Hippocampus (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>51.0 ± 4.0</td>
</tr>
<tr>
<td>Cervical cord (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>43.7 ± 4.8</td>
</tr>
<tr>
<td>Thoracic cord (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>35.3 ± 3.1</td>
</tr>
<tr>
<td>Lumbar cord (n = 31)</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>60-120</td>
<td>56.4 ± 3.7§</td>
</tr>
</tbody>
</table>

n = number of blood flow measurements made in this range of perfusion pressure.

*Difference between left and right cortical blood flow significant at 〈p < .05.
†Difference between brainstem and other regional brain flows significant at 〈p < .05.
‡Difference between cerebellar and other regional brain flows significant at 〈p < .01.
§Difference between lumbar and other regional cord flows significant at 〈p < .05.

cerebral blood flow of 59.2 ± 3.2 ml/100 g/min were comparable to those of other investigators using this technique in rats (table 2). De Ley et al17 using halothane (1%) and N2O (70%) anesthesia found that mean cerebral blood flow in the rat was 128 ml/100 g/min. Pannier et al,26 also using the microsphere technique, reported a mean cerebral blood flow of 75 ml/100 g/min in pentobarbital anesthetized rats. Our studies, like those of Pannier,26 were carried out using barbiturate anesthesia. It is not unexpected, therefore, that our values and those reported by Pannier26 would be lower than found by De Ley,17 in which halothane and N2O anesthesia was used. Halothane, a potent cerebral vasodilator, has repeatedly been shown to markedly increase cerebral blood flow. The effect of N2O on cerebral blood flow is more controversial.

Regional cerebral blood flow in our study demonstrated a significant difference between left and right cortical flows. Although collateral and posterior circulation would be expected to compensate for loss of carotid flow, the most likely explanation for the cortical flow differences was right carotid artery occlusion during catheter insertion. Regional cerebral blood flow in the rat has also been investigated by Nyström and Norlén.18 They found the following values for regional flows: cerebellar flow of 58 ml/100 g/min; brainstem flow of 54 ml/100 g/min; right hemisphere flow of 33 ml/100 g/min; left hemisphere flow of 38 ml/100 g/min; and cortical flow of 54 ml/100 g/min.

TABLE 2  Cerebral Blood Flow in the Rat

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Method</th>
<th>Anesthesia</th>
<th>CBF (ml/100 g/min) mean ± SEM</th>
<th>Area of brain</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Ley et al., 198517</td>
<td>microspheres</td>
<td>halothane</td>
<td>70% N2O</td>
<td>128 ± 12</td>
</tr>
<tr>
<td>Nyström et al., 198318</td>
<td>microspheres</td>
<td>thiopentobarbital</td>
<td>70% N2O</td>
<td>146 ± 14</td>
</tr>
<tr>
<td>Ishitsuka et al., 198219</td>
<td>hydrogen clearance</td>
<td>amobarbital</td>
<td>70% N2O</td>
<td>64.5 ± 5.5</td>
</tr>
<tr>
<td>Nilsson et al., 197620</td>
<td>133Xe inhalation</td>
<td>halothane</td>
<td>70% N2O</td>
<td>79.5 ± 2.4</td>
</tr>
<tr>
<td>Hernández et al., 197621</td>
<td>133Xe inhalation</td>
<td>Kety-Schmidt</td>
<td>70% N2O</td>
<td>103 ± 22 (SD)</td>
</tr>
<tr>
<td>Matsumoto et al., 197622</td>
<td>133Xe tissue direct count</td>
<td>AV shunt</td>
<td>70% N2O</td>
<td>86 ± 3</td>
</tr>
<tr>
<td>Gjedde et al., 197523</td>
<td>133Xe inhalation</td>
<td>Kety-Schmidt</td>
<td>70% N2O</td>
<td>98 ± 6</td>
</tr>
<tr>
<td>Eklöf et al., 197324</td>
<td>133Xe inhalation</td>
<td>Kety-Schmidt</td>
<td>70% N2O</td>
<td>100 ± 3</td>
</tr>
<tr>
<td>Goldman et al., 197325</td>
<td>14C-antipyrine indicator</td>
<td>fractionation technique</td>
<td>Awake</td>
<td>102 ± 3</td>
</tr>
<tr>
<td>Pannier et al., 197326</td>
<td>141Ce microspheres</td>
<td>Pentobarbital</td>
<td>Awake</td>
<td>79 ± 22 (SD)</td>
</tr>
<tr>
<td>Haining et al., 196827</td>
<td>hydrogen clearance</td>
<td>Awake</td>
<td>81 ± 25 (SD)</td>
<td>cerebellum</td>
</tr>
</tbody>
</table>
ml/100 g/min and left hemisphere flow of 38 ml/100 g/min. Although the values reported are lower than those found in our study, the same tendency was observed, namely higher flows in the cerebellum and brainstem than in the cortical regions. Goldman et al.23 also observed similar regional flow variations in pentobarbital anesthetized rats.

Fewer studies have investigated spinal cord blood flow. In the rat (Table 3), Rivlin and Tator24 measured blood flow at the T-1 level using the 14C-antipyrine technique. They reported values for gray and white matter of 61 and 15 ml/100 g/min respectively. Nyström and Norlén18 reported values for the cervical, upper thoracic, lower thoracic and lumbar regions of 48, 42, 74, and 98 ml/100 g/min respectively. It is apparent, therefore, that our values for spinal cord blood flow are comparable to those found by others.

The anatomic distribution of blood supply to the spinal cord is in concordance with findings of regional flow variations. The blood supply can be conceived as consisting of three divisions of arterial pathways.29 The primary division consists of the vertebral, costocervical, and lumbar arteries. The intermediate division consists of the radicular branches of the arterial trunks forming the primary divisions. The anterior and posterolateral spinal arteries make up the terminal division. It is the rudimentary development of the radicular branches of the intermediate division that renders the cord subject to ischemia. The branches are few in number: two or three for the cervical region, one for the superior thoracic region, and one large feeder called the artery of Adamkiewicz for the thoracolumbar cord.30 The wide spacing of the radicular feeders leaves large “watershed” areas along the course of the anterior spinal artery.29 In these watershed areas, the arterial inflow is precarious and interruption of any of the feeding radicular branches may have serious ischemic consequences.29 Their distribution provides an anatomic basis for regional flow variations.

The effects of variations of blood pressure on spinal cord blood flow have been investigated by Kindt,31 Griffiths,15 Kobrine et al,32 and Flohr et al.33 Kindt,31 using a surface flow device which measured qualitative changes only, reported that spinal cord blood flow did not change with systemic blood pressure elevation. Using the Xenon washout curve after direct intraparenchymal spinal cord injection, Griffiths15 demonstrated no significant change in white matter flow between 60-150 mm Hg. Below 60 mm Hg, flow decreased with further reductions in blood pressure. Kobrine et al.,32 using hydrogen clearance, also demonstrated that spinal cord blood flow in the white matter remained constant in the range of 50-135 mm Hg, indicating the presence of autoregulation. Similarly, Flohr et al.33 demonstrated with the particle distribution method that autoregulation was in effect between MAP 60-160 mm Hg.

Our study, which measured cerebral and spinal cord blood flows simultaneously, demonstrated that there was essentially no difference in the autoregulatory capacities of these two tissues. Autoregulation was functional between MAP of 60-120 mm Hg in both brain and spinal cord. Regional blood flows demonstrated similar autoregulatory patterns. Although this similarity has been implied by many investigators, little or no data exists which actually compares autoregulation in regional areas of both the brain and spinal cord.

Four theories have attempted to explain autoregulation in the cerebral vasculature. The myogenic theory, suggested by Bayliss in 1902,34 suggests that vascular smooth muscle has an inherent ability to contract in response to a rise in pressure within the vessel and relax in response to a fall in pressure. The tissue perfusion theory suggests that increased arterial blood pressure causes outward filtration of fluid which increases tissue pressure and decreases flow. A lower arterial pressure decreases the outward filtration fluid, reducing tissue pressure and increasing flow.35 The neurogenic theory proposes that autoregulation is mediated by periadventitial nerves in the cerebral vessels.36 Evidence suggests however, that these perivascular fibers play only a limited role in autoregulation. The blood flow changes in response to neurogenic stimulation are small. Maximal stimulation of the sympathetic nerves reduces cerebral blood flow by only 5-10%.37 Sympathetic stimulation has been shown to shift the limits of the autoregulatory curve. During hemorrhagic hypotension, the lower limit of autoregulation is shifted towards higher pressures.37 Neurogenic influences, therefore, although not necessary for the autoregulatory response to occur, do play a role in its modification. The metabolic theory suggests that changes in periarteriolar concentrations of metabolites mediate autoregulation. According to this theory, changes in perfusion pressure are initially reflected in altered flow. With altered flow, concentrations of perivascular substances, particularly CO2 and lactic acid tend to restore the initial cerebral blood flow.38 Of the mecha-

### Table 3: Spinal Cord Blood Flow in the Rat

<table>
<thead>
<tr>
<th>Author</th>
<th>Method</th>
<th>Anesthesia</th>
<th>SCBF (ml/100 gm/min)</th>
<th>Area of Spinal Cord</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyström et al, 1983</td>
<td>microspheres</td>
<td>thiobutabarbital</td>
<td>48±6</td>
<td>cervical</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>42±6</td>
<td>upper thoracic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>74±10</td>
<td>lower thoracic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>98±9</td>
<td>lumbar</td>
</tr>
<tr>
<td>Rivlin et al, 1978</td>
<td>14C-antipyrine</td>
<td>pentobarbital</td>
<td>61.4±2.9</td>
<td>T-1 gray matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.7±1.0</td>
<td>T-1 dorsal columns</td>
</tr>
</tbody>
</table>
nisms postulated, the myogenic and metabolic theories are the most widely accepted. There is evidence to suggest that spinal cord autoregulation is also a local phenomenon. The autoregulatory response of spinal cord white matter is preserved after severing the cord high in the neck, suggesting a local regulatory mechanism.

Autoregulation of cerebral blood flow has been demonstrated to be altered in a variety of circumstances. In chronic hypertension, cerebral blood flow autoregulation is adapted to higher pressures with a shift of the entire autoregulatory curve to the right. Autoregulation is also impaired in patients with head injury, brain tumors, and cerebral artery vasospasm. Hypoxia and hypercarbia also abolish cerebral autoregulation. Less information exists on alterations of spinal cord autoregulation. It has been shown to be impaired by hypoxia and hypercarbia. Conflicting results of the effects of spinal cord trauma have been reported, with some investigators reporting markedly increased blood flows and others reporting reduction in flows after cord injury. Little or no data exists on the effects of different anesthetic agents on spinal cord autoregulation. In this study, autoregulatory curves were established using a continuous intravenous infusion of pentothal in animals paralyzed with pancuronium. The need remains to establish autoregulatory curves for different anesthetic agents in both normal and cord injured animals.

The data presented here has demonstrated a coherent reference point in establishing an autoregulatory curve under barbiturate anesthesia. It has been established that experimental impact injury to the spinal cord will cause spinal cord edema, a condition that is also noted to be impaired by hypoxia and hypercarbia. It is possible that intraspinal cord compliance, like intracranial compliance, might be adversely affected because of the effects of anesthetia on autoregulation of spinal cord blood flow. This is an important area needing further clarification.

Conclusions

Autoregulation was demonstrated to be operative throughout the central nervous system. The parallelism between brain and spinal cord vascular dynamics was established. Autoregulatory curves for brain and spinal cord were virtually identical, with an autoregulatory range of 60–120 mm Hg perfusion pressure. Regional areas of the brain also had similar autoregulatory patterns. Further investigation of the effects of anesthetic agents on spinal cord blood flow both in the normal and cord-injured state is needed.

References

2. Fog M: Cerebral Circulation II. Reaction of pial arteries to increase in blood pressure. Arch Neurol Psychiatry 41: 260–268, 1939
32. Kobrine AI, Doyle TF, Rizzoli HV: Spinal cord blood flow as...
Evidence That Vasoactive Intestinal Polypeptide (VIP) Mediates Neurogenic Vasodilation of Feline Cerebral Arteries

JOSEPH E. BRAYDEN, PH.D., AND JOHN A. BEVAN, M.D.

SUMMARY In this study the magnitude of non-sympathetic, non-cholinergic neurogenic vasodilation of feline cerebral arteries in vitro was correlated with the extent of innervation by VIP-immunoreactive nerves. Well-innervated arteries underwent nerve-mediated relaxation whereas those that are not supplied with VIP-containing axons did not relax to transmural nerve stimulation. The relaxation of cerebral arteries that are well endowed with VIP-immunoreactive nerves was selectively and reversibly inhibited by VIP-specific antiserum. Substance P-specific antiserum did not affect the dilator responses. We conclude that VIP is a functional neuromediator transmitter in the cerebral circulation.

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ALTHOUGH VIP was first isolated from porcine small intestine and classified as a hormone,1, 2 VIP-like immunoreactivity was soon discovered within nerves that distribute to a number of organ systems.3-5 In 1976 Larsson and his colleagues6 described perivascular nerves that were immunoreactive for VIP within the cerebral circulation of the cat and this observation has since been confirmed by many investigators in a number of animal species.7-9 These findings imply that VIP is a cerebrovascular neurotransmitter but convincing evidence for such a possibility has been slow in forthcoming, primarily due to lack of a specific antagonist against the action of this peptide. However, the potent dilator action of VIP has led to suggestions of a neurovasodilator function.10, 11 In the present study we have used two separate approaches to study the possible role of VIP-immunoreactive (VIP-IR) nerves in the cerebral circulation. First, using in vitro techniques, we have studied non-cholinergic dilator responses of feline cerebral arteries that receive differing degrees of innervation by VIP-IR nerves, from dense to none, to elucidate possible correlations between innervation and physiological response. In addition, we have assessed the inhibitory actions of VIP-specific antiserum on non-adrenergic, non-cholinergic neurogenic vasodilator responses of the feline middle cerebral artery, a blood vessel that is richly endowed with VIP-IR nerves. Our findings support and confirm the previous suggestions of a specific vasodilator transmitter role for VIP in the cerebral circulation.

Methods

Adult, mongrel cats of either sex and weighing 4–5 kg were anesthetized with sodium pentobarbital and exsanguinated. The brain was quickly removed and placed in Krebs bicarbonate buffer that was gassed with 95% O2 and 5% CO2 (pH 7.4). In a first series of experiments, the anterior inferior cerebellar artery and a second order branch of the middle cerebral artery (lumen diameter: ~0.3 mm) were dissected from the brain and placed in Krebs solution. The cerebellar artery was separated into two segments, one proximal (diameter: ~0.3 mm) and one distal (diameter: ~0.25 mm) to the first major side branch of the artery. Cylindrical segments of these arteries (3 mm in length) were
Autoregulation of spinal cord blood flow: is the cord a microcosm of the brain?
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