Hypothalamic control of baroreceptor reflexes

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GEBBER, GERARD L., AND DAVID W. SNYDER. Hypothalamic control of the baroreceptor reflexes. Am. J. Physiol. 218(1): 124-131. 1969. The effect of hypothalamic stimulation was studied on the cardiac and vascular efferent components of the baroreceptor reflexes. Bradycardia evoked by carotid sinus nerve stimulation or norepinephrine was blocked by hypothalamic stimulation in spinal cats. These data demonstrate the existence of a suprabulbar system which functions to inhibit vagal bradycardia induced by baroreceptor activation. In contrast, baroreceptor modulation of central sympathetic outflow was functionally important during hypothalamic stimulation. The depressor response produced by carotid sinus stretch was not reduced by hypothalamic stimulation in vagotomized cats. The pressor response evoked by hypothalamic stimulation was markedly enhanced during carotid occlusion or following section of the carotid sinus nerves. Also, peripheral sympathetic nerve discharges elicited by hypothalamic stimulation were reduced when arterial pressure was raised. It is concluded that tachycardia associated with the pressor response evoked by hypothalamic stimulation was the result not only of increased cardiac sympathetic nerve activity, but also of inhibition of baroreceptor-induced vagal activation.

MATERIALS AND METHODS

Sixty-five cats were anesthetized by the intravenous injection of chloralose (40-55 mg/kg) or by the intraperitoneal administration of a mixture of sodium dialylbarbiturate (70 mg/kg), urethan (280 mg/kg), and monoethylurea (280 mg/kg). A heating pad was used to maintain rectal temperature at 38 C. Eight experiments also were performed on artificially respired unanesthetized spinal cats. Transection of the spinal cord at the C1 vertebra was accomplished under methoxyflurane anesthesia. The muscles overlying the skull were infiltrated with 1% procaine hydrochloride in unanesthetized preparations.

Blood pressure was recorded from a femoral artery with a Statham P23 series pressure transducer and displayed on a Grass polygraph. Heart rate was plotted from the blood pressure tracing. Drugs were administered into a femoral vein.

Marked alterations in respiration were observed during hypothalamic stimulation in 28 of the 54 cats in which the neuraxis was intact. In order to avoid cardiovascular responses which might have arisen as the result of centrally induced respiratory effects, these cats were immobilized with decamethonium bromide (0.5 mg/kg, iv) and placed on artificial respiration. The hypothalamic-baroreceptor interactions studied were not changed by the neuromuscular blocking agent.

The method of carotid sinus stretch was employed in eight cats. Either the left or right carotid sinus was partially isolated using a technique similar to that described by Wilson et al. (18). After ligating the external carotid artery, a cannula was inserted into the common carotid artery and moved to the area of the carotid bifurcation. A small volume of heparinized saline was pulsed into the carotid bifurcation from a syringe, at a frequency which approximated that of the animal's heart rate. In this manner, carotid sinus pressure was raised to approximately 200 mm Hg for 20-30 sec. Carotid sinus pressure was recorded with a Statham transducer connected to a side arm leading from the carotid cannula.

Baroreceptor Activation

The method of carotid sinus stretch was employed in five cats. Either the left or right carotid sinus nerve was stimulated in five cats. The nerve was exposed from a ventral aspect after reflection of a portion of the trachea and esophagus. Bipolar platinum electrodes were placed on the carotid sinus nerve near its junction with the glossopharyngeal nerve. The nerve was crushed peripheral to the electrode placement. Parameters of stimulation required to evoke
maximal bradycardia were 1–10 v; 100–300 cycles/sec, and 0.1–1 msec.

Activation of the arterial pressoreceptors was accomplished also by the injection of pressor doses of norepinephrine into the femoral vein.

**Baroreceptor Denervation**

Denervation of the carotid sinus baroreceptors was denoted by abolition of the pressor response evoked by occlusion of the common carotid arteries. The vagus nerves were exposed and sectioned in the midsclcral area.

**Electrical Stimulation**

Stimuli were applied to selected areas of the hypothalamus by means of a square-wave stimulator, the output of which was passed through a stimulus isolation unit to small bipolar stainless steel electrodes. The stimulating electrodes were insulated with epoxylite and separated by 0.5 mm at the bared tips. The electrodes were stereotaxically positioned according to the coordinates of Snider and Niemer (17). Parameters of stimulation were 2–15 v; 5–100 cycles/sec and 0.2–2 msec. Periods of stimulation varied from 5 to 120 sec.

**Electrode Placement**

At the end of each experiment, the brain was removed and fixed in 10% formalin. Most brains were sectioned grossly to determine the site of electrode placement. In representative experiments, electrode positions were histologically verified after the formalin-fixed brain was embedded in paraffin, sectioned at 20 μ thickness, and stained by the Weil method.

**Sympathetic Nerve Recording**

The procedures used to monitor centrally emanating preganglionic and postganglionic sympathetic nerve activity have been described in detail by Gebber (2). Bipolar platinum electrodes were used to record postganglionic action potentials from the external carotid branch of the left superior cervical ganglion and from the inferior cardiac branch of the left or right stellate ganglion. One electrode was placed on the crushed peripheral end of the postganglionic nerve and the other on an intact portion of the nerve. Centrally emanating preganglionic activity was recorded in a similar fashion from the left or right splanchnic nerve. Electrodes were placed on the splanchnic nerve below the diaphragm and near its entrance to the celiac ganglion. Nerve recordings were amplified with a Grass 7P3A capacitance-coupled preamplifier and displayed on a Grass polygraph with low and high half-amplitude responses at 10 and 75 cycles/sec.

**Drugs**

The following drugs were used: norepinephrine bitartrate, acetylcholine chloride, and atropine sulfate. All doses are expressed in terms of the salt.

**RESULTS**

**Comparison of Cardiovascular Responses Evoked by Hypothalamic Stimulation and Norepinephrine**

Both the left and right sides of the hypothalami were explored 7–10 mm anterior to the interaural line and 1–4 mm lateral to the midline. Using the terminology of Snider and Niemer (17), pressor responses were consistently evoked from the area hypothalami posterior (A, Lor R4, H-1 to -3), area hypothalami lateralis (A, Lor R3, H-1 to -3) and from the area medial to the zona incerta and fields of Fore (A, Lor R5, H 0 to -3). These pressor areas have been previously described and illustrated (4, 9, 12, 18). The threshold intensity of hypothalamic stimulation required to evoke a pressor response was 3–5 v. The pressor response became maximum at 10–15 v; 50 cycles/sec and 1–2 msec. The latency of onset of the pressor response varied from 1 to 5 sec and appeared related to the particular experimental preparation rather than to the site of hypothalamic stimulation.

The pressor response was accompanied by an increase in heart rate (from 12 to 96 beats/min) in cats in which the vagus nerves were intact (55 experiments). The degree of tachycardia associated with the maximum pressor effect produced by stimulation of two or more distinct hypothalamic sites in the same cat was essentially the same. Bradycardia was never observed during the rise in blood pressure produced by central stimulation. A representative response is illustrated in Fig. 1A.

In contrast, the pressor response evoked by the intravenous injection of norepinephrine (0.5–2 μg/kg) was associated with bradycardia (20 experiments). A representative response is illustrated in Fig. 1B. Whereas atropine (0.25–0.5 mg/kg iv) reversed bradycardia and enhanced the hypertensive response evoked by norepinephrine, administration of the cholinergic blocking agent failed to alter the cardiovascular response induced by hypothalamic stimulation (six experiments). The effects of atropine are illustrated in Fig. 1.

**Inhibition of Baroreceptor-Induced Bradycardia by Hypothalamic Stimulation in Spinal Cat**

The results obtained with atropine suggested that the baroreceptors failed to activate efferent cardiac vagal fibers during the pressor response evoked by hypothalamic stimulation. This was tested in spinal cats.

After locating one or more sites in the hypothalamus from which an increase in blood pressure and heart rate could be evoked, the spinal cord was sectioned at the C1 vertebra. The effect of hypothalamic stimulation was tested on bradycardia evoked by intravenous norepinephrine or stimulation of the carotid sinus nerve.

Figure 2 illustrates the effect of hypothalamic stimulation on reflex bradycardia evoked by the intravenous injection of 2 μg/kg of norepinephrine. The pressor response evoked in the spinal cat by norepinephrine was accompanied by bradycardia (Fig. 2A). Hypothalamic stimulation failed to alter blood pressure or heart rate of the spinal cat in the absence of norepinephrine (Fig. 2B). However, hypothalamic stimulation interrupted bradycardia which was
FIG. 1. Comparison of effects of atropine on cardiovascular responses evoked by hypothalamic stimulation and norepinephrine. A: solid line, changes in heart rate and blood pressure evoked by stimulation of right area hypothalami posterior at 15 v; 50 cycles/sec and 1 msec for 30 sec. Dotted line, same but 10 min following iv administration of 0.33 mg/kg of atropine. Duration of hypothalamic stimulation is denoted by solid line and dotted line below the abscissa. B: solid line, response evoked by 1.5 ug/kg of norepinephrine injected at time 0. Dotted line, same but 15 min after administration of atropine. Blood pressure and heart rate were plotted at 5-sec intervals.

FIG. 2. Effect of hypothalamic stimulation on bradycardia produced by norepinephrine in spinal cat. Panel A: Increase in blood pressure and reflex bradycardia produced by iv injection of norepinephrine (2 ug/kg) following transection of spinal cord at the C1 vertebra. Panel B: stimulation of left area hypothalami posterior at 10 v; 25 cycles/sec and 1 msec in absence of norepinephrine. Hypothalamus was stimulated between the downward deflections of time base (1 sec/division). Panel C: effect of hypothalamic stimulation during bradycardia evoked by norepinephrine. Panel D: norepinephrine response 10 min after iv injection of 0.5 mg/kg of atropine.

FIG. 3. Plot of data in Fig. 2 which illustrates degree of inhibition of norepinephrine-induced bradycardia by hypothalamic stimulation in spinal cat. Solid line, changes in heart rate and blood pressure evoked by norepinephrine injected at time 0. Dotted line, effect of hypothalamic stimulation on norepinephrine response. Duration of hypothalamic stimulation is denoted by dotted line below abscissa. Dotted-dashed line, norepinephrine response following administration of atropine. Blood pressure and heart rate were plotted at 5-sec intervals.

Inhibition of norepinephrine-induced bradycardia occurred within 1-2 sec. Bradycardia evoked by norepinephrine was reversed following the administration of atropine (0.5 mg/kg iv) (Fig. 2D).

The completeness of inhibition of norepinephrine-induced bradycardia is more clearly shown in Fig. 3. Hypothalamic stimulation, initiated during norepinephrine-induced bradycardia, raised heart rate to essentially the same level as that reached during the pressor response evoked by norepinephrine following the administration of atropine.

Figure 4 illustrates that hypothalamic stimulation was equally effective in blocking bradycardia evoked by electrical stimulation of the carotid sinus nerve in the spinal cat. Although bradycardia evoked by baroreceptor activation was more pronounced in unanesthetized than in anesthetized spinal cats, hypothalamic stimulation was equally effective in blocking bradycardia in all preparations. Inhibition of bradycardia evoked by norepinephrine or carotid sinus
Cardia was somewhat delayed in onset when compared to heart rate. The effect of bilateral vagotomy on heart rate of essentially completely independent of whether the left or cycles/set and 1 msec. Inhibition of bradycardia evoked section (19 experiments), The parameters of hypothalamic which increased blood pressure and heart rate before spinal section of the ipsilateral carotid sinus nerve. Either ipsi-

nerve stimulation was produced by electrical activation of each and every site in the lateral and posterior hypothalamus which increased blood pressure and heart rate before spinal section (19 experiments). The parameters of hypothalamic stimulation required to produce optimal inhibition of baroreceptor-induced bradycardia were 7–12 v; 10–20 cycles/sec and 1 msec. Inhibition of bradycardia evoked by carotid sinus nerve stimulation or norepinephrine was essentially completely independent of whether the left or right hypothalamus was stimulated separately or simultaneously. Bradycardia induced in the spinal cat, by baroreceptor activation, was abolished by bilateral vagotomy (four experiments) or by the intravenous injection of 0.25–0.5 mg/kg of atropine (eight experiments).

Figure 4 also shows that hypothalamic stimulation sometimes was associated with an increase in heart rate and blood pressure of the spinal cat. This occurred in 10 of the 19 spinal cats studied. In these experiments, bilateral vagotomy or atropine (0.25 to 0.5 mg/kg iv) raised heart rate and blood pressure to the level produced by hypothalamic stimulation. Subsequent stimulation of the hypothalamus failed to change heart rate. The effect of bilateral vagotomy on heart rate of the spinal cat is illustrated in Fig. 4.

Effect of Hypothalamic Stimulation on Cardiovascular Response Evoked by Carotid Sinus Stretch in Cats in Which Neuraxis Was Intact

Changes in blood pressure and heart rate produced by pulsatile stretch of the left or right partially isolated carotid sinus were monitored in eight cats. Carotid sinus stretch of 20–30 sec produced a decrease in blood pressure and heart rate in preparations in which both vagi and the contralateral carotid sinus nerve were intact (four experiments). Unlike the response observed in dogs (18), bradycardia was somewhat delayed in onset when compared to the depressor response. These effects were abolished by section of the ipsilateral carotid sinus nerve. Either ipsilateral, contralateral, or bilateral hypothalamic stimulation abolished bradycardia but failed to alter significantly the

Table 1. Effect of hypothalamic stimulation on depressor responses (Δ mean blood pressure) produced by carotid sinus stretch and intravenous acetylcholine

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Hypothalamic Stimulation</th>
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<tr>
<td>BP mm Hg</td>
<td>CSS mm Hg</td>
<td>ACh mm Hg</td>
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<tr>
<td>A) Cats in which both vagus nerves and the contralateral carotid sinus nerve were intact, N = 4</td>
<td>113 ± 2</td>
<td>26 ± 4</td>
</tr>
<tr>
<td>B) Cats in which both vagus nerves and the contralateral carotid sinus nerve were sectioned, N = 4</td>
<td>122 ± 4</td>
<td>39 ± 2</td>
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Values are means ± se. BP = mean blood pressure; CSS = depressor response evoked by carotid sinus stretch; ACh = depressor response evoked by acetylcholine; N = number of experiments.

Figure 5. Effect of hypothalamic stimulation on cardiovascular response evoked by carotid sinus stretch in a cat in which neuraxis and vagus nerves were intact. Solid line, changes in heart rate and blood pressure produced by pulsatile increase of right carotid sinus pressure from 50 to 200 mm Hg for 15 sec. Duration of carotid sinus stretch is denoted by the solid line below abscissa and is same for following 2 test situations. Dotted line, response to carotid sinus stretch during bilateral stimulation of area hypothalami lateralis at 15 v; 30 cycles/sec and 2 msec. Dotted-dashed line, response to carotid sinus stretch following iv administration of 0.25 mg/kg of atropine. Blood pressure and heart rate were plotted at 5-sec intervals.
in which the vagi and contralateral carotid sinus nerve were previously cut. Carotid sinus stretch failed to evoke bradycardia in these preparations. However, the fall in blood pressure produced by carotid sinus stretch was greater than in those experiments in which the vagi and contralateral carotid sinus nerve were intact (Table 1B). The absolute magnitude of the depressor responses evoked by carotid pulsation and by the intravenous injection of 0.1-0.5 μg/kg of acetylcholine was increased during the pressor response evoked by hypothalamic stimulation (Table 1B). A representative experiment is illustrated in Fig. 6.

**Hypothalamic-Baroreceptor interactions on central sympathetic outflow**

Whereas the experiments with spinal animals indicated that hypothalamic stimulation was associated with inhibition of baroreceptor-induced vagal bradycardia, those with carotid sinus stretch suggested that the baroreceptors were capable of influencing central sympathetic outflow during diencephalic activation. This was tested in the experiments described below.

A) **Effect of carotid occlusion and baroreceptor denervation on pressor response evoked by hypothalamic stimulation.** The interactions observed between the pressor responses evoked by bilateral occlusion of the common carotid arteries and hypothalamic stimulation are summarized in Table 2. Centrally evoked blood pressure responses were elicited with supramaximal parameters of stimulation. All experiments were performed on vagotomized cats.

The pressor response evoked by hypothalamic stimulation was enhanced to a mean of 188% of control during bilateral occlusion of the common carotid arteries. A representative experiment is shown in Fig. 7. Enhancement was observed independent of whether hypothalamic stimulation was unilateral or bilateral. The degree of enhancement of equivalent pressor responses evoked by stimulation of two or more sites in the same cat was essentially the same. Bilateral section of the carotid sinus nerves enhanced the pressor response evoked by hypothalamic stimulation to the same or a greater degree than that observed during carotid occlusion (three experiments). This is shown in Fig. 7. In addition, the threshold of hypothalamic stimulation required to evoke a pressor response was reduced from 3-5 v to 1-2 v during carotid occlusion or following carotid sinus nerve section (three experiments).

**Fig. 6.** Comparison of effect of hypothalamic stimulation on change in blood pressure produced by carotid sinus stretch and acetylcholine. Both vagi and left carotid sinus nerve were sectioned in this cat. Panel A: reflex fall in blood pressure produced by right carotid sinus stretch. Top tracing is right carotid sinus pressure. Middle tracing is blood pressure. Bottom tracing is time base (1 sec/division). Panel B: response to carotid sinus stretch during bilateral stimulation of the hypothalamus near the fields of Forel at 10 v; 50 cycles/sec and 1 msec. Hypothalamus was stimulated between downward deflections of time base. Panel C: depressor response produced by iv injection of 0.1 μg/kg of acetylcholine. Acetylcholine injection is marked by downward deflection of the base-line. Panel D: acetylcholine response during hypothalamic stimulation. Downward deflections of time base are from left to right: hypothalamic stimulation on; acetylcholine injection; hypothalamic stimulation off.

**Table 2. Interaction between pressor responses (Δ mean blood pressure) evoked by hypothalamic stimulation and bilateral occlusion of common carotid arteries in vagotomized cats**

<table>
<thead>
<tr>
<th>Control</th>
<th>Test Responses</th>
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<tbody>
<tr>
<td><strong>BP, mm Hg</strong></td>
<td><strong>Hypo, mm Hg</strong></td>
</tr>
<tr>
<td>BP A 0</td>
<td>Hypo during CO, mm Hg</td>
</tr>
<tr>
<td>105 ± 5</td>
<td>41 ± 4</td>
</tr>
<tr>
<td>77 ± 8</td>
<td>53 ± 5</td>
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</table>

Values are means ± s.e. BP = mean blood pressure. Hypo = pressor response evoked by hypothalamic stimulation. CO = pressor response evoked by bilateral occlusion of the common carotid arteries. Hypo during CO = pressor response evoked by hypothalamic stimulation during carotid occlusion. CO during hypo = pressor response evoked by carotid occlusion during continuous hypothalamic stimulation. Numbers in parentheses = numbers of experiments.

**Fig. 7.** Hypothalamic-baroreceptor interactions in vagotomized cat. Panel A: pressor response produced by bilateral occlusion of common carotid arteries. Carotid occlusion was performed between downward deflections of time base (1 sec/division). Panel B: pressor response evoked by bilateral stimulation of hypothalamic stimulation of hypothalamus near fields of Forel at 15 v; 50 cycles/sec and 2 msec. Hypothalamus was stimulated between downward deflections of time base. Panel C: hypothalamic response during carotid occlusion. Downward deflections of time base are, from left to right: carotid occlusion, hypothalamic stimulation on, hypothalamic stimulation off, release of carotid occlusion. Panel D: carotid occlusion response during hypothalamic stimulation. Downward deflections of time base are, from left to right: hypothalamic stimulation on, carotid occlusion, release of carotid occlusion, hypothalamic stimulation off. Panel E: absence of carotid occlusion response following bilateral section of carotid sinus nerves. Panel F: hypothalamic response following section of carotid sinus nerves.
HYPOTHALAMIC-BARORECEPTOR INTERACTIONS

B) Hypothalamic and baroreceptor influences on peripheral sympathetic nerve activity. Hypothalamic stimulation evoked an immediate increase in nerve activity recorded from the external carotid branch of the left superior cervical ganglion (four experiments), inferior cardiac branch of the left or right stellate ganglion (three experiments), and left or right preganglionic splanchnic nerve (four experiments). The characteristics of the evoked response are illustrated in Fig. 8. As previously reported (8), nerve discharges were evoked by either ipsilateral or contralateral hypothalamic stimulation. Ipsilateral stimulation, however, evoked a greater increase in peripheral sympathetic nerve activity. Cessation of stimulation was accompanied by a short period of partial or complete inhibition of tonic nerve activity. This phenomenon has been previously described in detail (5, 8, 13).

Gebber (2) reported that bilateral section of the carotid sinus and vagus nerves abolished inhibition of centrally emanating sympathetic nerve activity associated with the pressor effect of norepinephrine in the cat. In the present study, it was observed that discharges evoked in the external carotid, inferior cardiac, and splanchnic nerves, by hypothalamic stimulation, were reduced or abolished during the pressor response evoked by the intravenous administration of 1-2 μg/kg of norepinephrine. When systolic blood pressure was raised to a level between 150 and 200 mm Hg, nerve discharges evoked by low frequencies of hypothalamic stimulation (5-10 cycles/sec) were essentially abolished. Discharges evoked by higher frequencies of stimulation (25-50 cycles/sec) were markedly attenuated. This is illustrated in Fig. 8. When systolic blood pressure was raised above 200 mm Hg, nerve discharges evoked by the higher frequencies of hypothalamic stimulation were barely observable. These observations were indistinguishable for all three sympathetic nerves studied. These results are in general agreement with those of Ninomiya et al. (7).

DISCUSSION

This study demonstrates that the efferent cardiac vagal component of the baroreceptor reflexes can be inhibited by the hypothalamus. This was clearly indicated by the results obtained in encéphale isolé preparations. Hypothalamic stimulation inhibited bradycardia evoked by carotid sinus nerve stimulation or norepinephrine in the spinal cat. Bradycardia induced by baroreceptor activation was abolished by atropine or bilateral vagotomy in spinal cats. Inhibition of bradycardia was produced by stimulation of each and every hypothalamic site which increased blood pressure and heart rate before spinal section. The almost instantaneous effect of hypothalamic stimulation on bradycardia evoked by norepinephrine strongly suggests that the inhibition was of neuronal origin.

It is apparent that the site of inhibition of vagal activation was in the central nervous system. Inhibition of bradycardia evoked by carotid sinus nerve stimulation removed the possibility of a direct action of the hypothalamus on the arterial pressoreceptors. Interruption of central sympathetic outflow, by spinal section, virtually eliminated the possibility that inhibition of baroreceptor-induced bradycardia was due to a peripheral interaction between neurogenically released norepinephrine and acetylcholine. This was supported...
by the observation that hypothalamic stimulation, in the absence of baroreceptor activation, produced little or no change in heart rate of the spinal animal. In those spinal animals in which hypothalamic stimulation produced an increase in heart rate, atropine or bilateral vagotomy induced a sustained and equivalent tachycardia.

Inhibition of the cardiac vagal component of the baroreceptor reflexes also was demonstrated in cats in which the neuraxis was intact. Atropine-sensitive bradycardia evoked by carotid sinus stretch was blocked by hypothalamic stimulation. In contrast, hypothalamic stimulation failed to inhibit bradycardia produced by stimulation of the peripheral end of the cut vagus. Inhibition of baroreceptor-evoked vagal bradycardia also was suggested by the failure of atropine to alter the increase in heart rate and blood pressure produced by hypothalamic stimulation. In contrast, atropine reversed bradycardia and enhanced the accompanying pressor response evoked by norepinephrine. Thus, the data strongly indicate that tachycardia associated with the pressor effect evoked by hypothalamic stimulation, in the intact cat, was the result not only of increased cardiac sympathetic nerve activity (8), but also of inhibition of baroreceptor-induced vagal activation.

Either depression or potentiation of baroreceptor reflex responsiveness has been reported during electrical activation of various portions of the cat brain (3, 6, 10, 16). Most relevant to this investigation is the work of Smith and Nathan (16). These investigators noted that electrical stimulation of the medial portion of the inferior olive occasionally blocked the depressor response and bradycardia produced by carotid sinus stretch in the cat. Since a projection from the diencephalon to the inferior olive has been demonstrated (14, 15), Smith and Nathan suggested that the hypothalamus might exert an inhibitory influence on the carotid sinus reflex. Although the present investigation demonstrated such an inhibitory influence on baroreceptor-induced vagal activation, baroreceptor control of central sympathetic outflow remained functionally important during stimulation of the hypothalamus.

First, hypothalamic stimulation failed to reduce the depressor response produced by carotid sinus stretch in vagotomized cats. Second, discharges evoked in the splanchnic, inferior cardiac, and external carotid sympathetic nerves, by hypothalamic stimulation, were reduced during the pressor response evoked by norepinephrine. Thirdly, the pressor response evoked by hypothalamic stimulation was enhanced to 188% of control during bilateral occlusion of the common carotid arteries or following baroreceptor denervation. Carotid occlusion and baroreceptor denervation also lowered the threshold voltage of hypothalamic stimulation required to evoke a rise in blood pressure. Finally, the rise in blood pressure induced by carotid occlusion was enhanced to 241% of control during the pressor response evoked by hypothalamic stimulation. This observation may be explained in the following manner. The pressor response evoked by hypothalamic stimulation undoubtedly was accompanied by an increase in baroreceptor nerve traffic. This increase in inhibitory afferent discharge limited the rise in blood pressure produced by continued hypothalamic activation. Consequently, carotid occlusion would evoke an enhanced pressor response by eliminating the negative feedback effect of the baroreceptors on the increase in central sympathetic outflow induced by hypothalamic stimulation. The site of the proposed interaction between baroreceptor and hypothalamic influences on central sympathetic outflow remains to be determined.

Thus, it is clear that the baroreceptor reflexes were important in controlling the increase in central sympathetic outflow induced by hypothalamic stimulation. Nevertheless, the available data do not preclude a modulating effect of the hypothalamus on baroreceptor sympathetic reflexes. Although carotid occlusion or baroreceptor denervation approximately doubled the pressor response evoked by hypothalamic stimulation, it was not ascertained whether baroreceptor sympathetic reflex responsiveness was maximum under the existing experimental conditions.

A question which must be entertained is whether the cardiovascular response evoked by hypothalamic stimulation can be equated to a normal physiological reaction. Alternatively, was the simultaneously occurring pressor response and inhibition of baroreceptor-induced vagal activation due to coincidental stimulation of neuronal systems which are not functionally related in the physiological state? In this regard, it is perhaps significant that the cardiovascular response evoked by hypothalamic stimulation closely simulates that observed during muscular exercise (11, 12, 18). Thus, high arterial pressure and heart rate are characteristic of at least one well studied physiological situation. The observation that such a response could be elicited by stimulation of widely separated areas of the posterior and lateral hypothalamus also suggests that simultaneous activation of pathways which enhanced central sympathetic outflow and inhibited vagal activation was not coincidental.

In conclusion, this study demonstrates the existence of a suprabulbar system which functions to inhibit the cardiac vagal response to baroreceptor activation. Electrical activation of this system from the hypothalamus is coupled with increased sympathetic discharge to the heart and vasculature.

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