Effects of Sudden Aortic Occlusion on Heart Rate After Sino-Aortic Denervation

By THOMAS M. GILFOIL, M.S., PH.D.

This study tests the possibility that pressoreceptors of the sinoaortic type may be located in thoracic vessels and innervated by thoracic afferent nerves. Heart rate and arterial pressure were recorded in anesthetized dogs with neural pathways intact, bilateral vagotomy and sinoaortic denervation before and after internal occlusion of the aorta just above the celiac artery. Results obtained indicate that after elimination of the sinoaortic mechanisms by vagotomy and isolation of the carotid sinuses no functional pressoreceptors of the sinoaortic type can be demonstrated in the arterial tree above the celiac artery.

REFLEX depression of cardioaccelerator tonus is produced by impulses arising in pressoreceptors in the sinoaortic areas,1-4 the cardiac wall,5-7 and the pulmonary vessels.7-12 The afferent limb of the reflex is contained in the carotid sinus nerves or the vagodepressor trunks. Reflex vasodilatation of skeletal vascular beds by activation of stretch receptors in the descending thoracic aorta was recently demonstrated.13 The receptors involved were shown to be innervated by thoracic dorsal roots and not by the vagodepressor trunk. The experiments described were designed to test the possibility that pressoreceptors of the sinoaortic type may be located in the thoracic vessels and innervated by extravagal thoracic afferent nerves.

METHODS

Experiments were performed on 20 mongrel dogs. Thirteen were given morphine sulfate (2 to 3 mg./Kg.) subcutaneously followed by alpha chloralose (75 mg./Kg.) intravenously; 5 were anesthetized with sodium pentobarbital (33 mg./Kg.) intravenously, and 2 were given morphine sulfate (2 mg./Kg.) followed by ether. Blood pressure was recorded from the left common carotid artery with a mercury manometer or a Sanborn pressure transducer. Respiration was recorded with a pneumograph and tambour, and electrocardiographic tracings were taken from lead II. A device for obstructing the aorta was arranged as follows. A no. 7 ureteral catheter having a small balloon attached to its tip was inserted into the right femoral artery and advanced far enough (estimated by measuring the distance from the femoral incision to the apex beat) to locate the balloon about 2 to 3 cm. above the celiac artery. The position of the balloon was checked postmortem. By means of a T tube the free end of the catheter was attached to a mercury manometer and a 20 ml. syringe. To occlude the aorta sufficient water was forced from the syringe into the balloon to establish a pressure of 250 ± 10 mm. Hg. Absence of a pulse in the femoral artery was taken as an indication of effective aortic obstruction. When pressure was produced within the balloon, the pressure in the arterial tree above the site of obstruction usually increased to this level within a few seconds. Rapid and complete removal of the obstruction was effected by withdrawing water into the syringe to create a negative pressure in the system. When the balloon was empty, pulsations of virtually normal strength could be felt in the femoral artery.

Continuous electrocardiographic tracings were taken from the animals having all neural pathways intact beginning at least 10 sec. before aortic obstruction and continuing throughout a period of obstruction lasting 50 sec. This procedure was repeated in 13 of the 20 dogs after vagotomy and again in all but one of these after complete sinoaortic denervation. Seven of the 20 dogs were subjected to this procedure only before and after complete sinoaortic denervation. The heart rates were determined by counting the number of cycles per 10 sec. period. Rates are expressed as beats per minute in the table and graphs.

The carotid sinuses (and bodies) were denervated by ligating the common carotid arteries at least 2 to 3 cm. below the bifurcation. The internal and external carotid arteries were in-
individual ligations about 1 cm. above the bifurcation. The occipital, thyroid and lingual arteries were usually ligated separately. The common carotid arteries were then cut open and lack of bleeding indicated that the areas enclosed by the ligatures were devoid of a blood supply. The aortic pressoreceptors (and bodies) were denervated by sectioning the vagosympathetic trunk high in the neck. Denervation of the carotid and aortic zones was verified by intravenous injection of sodium cyanide before and after the surgical procedures. It has been demonstrated that when cyanide reaches the carotid and aortic bodies through their blood supply respiratory stimulation results before sinoaortic denervation but is negligible or absent after sinoaortic denervation.14-16

It is known that the pressoreceptors and chemoreceptors are located in proximity to each other, thus inability to produce stimulation of breathing upon injection of cyanide after sinoaortic denervation provides indirect evidence that the sinoaortic pressoreceptors, as well as the chemoreceptors, are isolated.

RESULTS

Intravenous injection of 2 mg. of sodium cyanide elicited the typical respiratory stimulation in all dogs before but not after sinoaortic denervation. Heart rates for each animal under the different conditions of each experiment are listed in table 1. Average heart rates of the 5 dogs anesthetized with sodium pentobarbital and the 13 dogs anesthetized with morphine sulfate-chloralose are presented graphically in figures 1 to 3. Aortic occlusion in all 20 dogs with neural pathways intact was followed by a reduction in heart rate. The lowest rate reached, usually in the first or second 10 sec. period following aortic occlusion, ranged from 18 to 173 beats/min. lower than the control rates. Average control heart rates in normally innervated dogs anesthetized with morphine sulfate-chloralose are lower (figs. 2 and 3) than the average control heart rates of normally innervated dogs anesthetized with sodium pentobarbital (fig. 1). Cardiac slowing in response to aortic occlusion is greater in the latter, and, in the animals anesthetized with morphine sulfate-chloralose, is greater in the

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**Table 1.** Effects of Aortic Occlusion on Heart Rate

<table>
<thead>
<tr>
<th>Dog no.</th>
<th>Neural pathways intact</th>
<th>Bilaterally vagotomized</th>
<th>Sinoaortic denervated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H.R. (per min.) control</td>
<td>mm Hg rise in M.A.P. by occlusion</td>
<td>Maximal change in H.R. after occlusion</td>
</tr>
<tr>
<td>1</td>
<td>197 45 -24 180 54 -12</td>
<td>222 48 -5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>187 66 -31 156 50 -17</td>
<td>191 84 +3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>192 42 -18 186 60 -10</td>
<td>204 110 0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>168 50 -18 156 60 -12</td>
<td>168 60 0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>162 45 -28 150 50 -12</td>
<td>103 80 0</td>
<td></td>
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<td>6</td>
<td>85 30 -19 134 40 -10</td>
<td>108 45 +2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>222 35 -173 210 45 -35</td>
<td>240 50 -5</td>
<td></td>
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<td>8</td>
<td>204 45 -103 215 55 -17</td>
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<td>9</td>
<td>177 55 -79 270 90 -16</td>
<td>288 90 +2</td>
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<td>10</td>
<td>102 60 -66 169 46 +1</td>
<td>204 60 +1</td>
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<td>11</td>
<td>60 30 -21 170 40 -14</td>
<td>216 90 0</td>
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<td>84 36 -24 156 40 -12</td>
<td>192 70 0</td>
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<td>114 42 -24 134 40 -12</td>
<td>199 70 +5</td>
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<td>84 24 -30 120 40 -12</td>
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<td>108 56 -24 210 56 -10</td>
<td>204 50 0</td>
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<tr>
<td>20</td>
<td>179 35 -17 174 45 -6</td>
<td>194 50 -1</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: H.R.—heart rate; M.A.P.—mean arterial pressure.
* Anesthetic: Dogs 1-5—pentobarbital; 6-18—morphine-chloralose; and 19 and 20—morphine-ether.
† Heart rate for 10 sec. period before aortic occlusion.
— Not recorded or not tested.
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Fig. 1 Top. Effect of aortic occlusion on heart rate in 5 dogs anesthetized with sodium pentobarbital. In this and in the following figures the symbol at 0 time indicates the average of the heart rates per minute for the 10 sec. period preceding the time of aortic occlusion, and the following symbols indicate the averages of the rates for the consecutive 10 sec. periods during occlusion.

Fig. 2 Bottom. Effect of aortic occlusion on heart rate in 6 dogs anesthetized with morphine sulfate-chloralose. These were tested after vagotomy and again after isolating the carotid sinuses.

Normally innervated than in the vagotomized preparation (fig. 2). However, the degree of cardiac inhibition elicited by aortic occlusion in dogs anesthetized with sodium pentobarbital is approximately the same in the normally innervated as in the vagotomized state (fig. 1). Vagotomy typically was followed by an elevation of control heart rate in animals anesthetized with morphine sulfate-chloralose (fig. 2). The 5 dogs anesthetized with sodium pentobarbital responded to bilateral vagotomy by a reduction in control heart rate (fig. 1) ranging from 6 to 31 beats/min. This indicates that a moderate degree of vagal cardioinhibitory tonus was present in the former group but not in the latter. Vagal cardioaccelerator, as well as cardioinhibitory, fibers have been demonstrated in the dog. It is apparent that in the animals anesthetized with sodium pentobarbital efferent vagal cardiac impulses are predominant in cardioaccelerator fibers, hence the cardiac slowing which occurred in these animals following vagotomy. In 12 of the 13 vagotomized dogs aortic obstruction elicited a slowing of the heart rate. The maximal decrease ranged from 6 to 35 beats/min. lower than the control levels and occurred most frequently within the second 10 sec. period after obstruction, but in a few instances the maximal decrease
occurred in the first, third or fourth 10 sec. periods. When the t-test is applied to these results the decrease in heart rate is found to be highly significant. A further elevation in control heart rate over that recorded in the intact and vagotomized state followed complete sinoaortic denervation in 18 of the 20 animals. In sinoaortic denervated animals aortic obstruction did not cause changes in heart rate. Heart rates occurring in these animals at the second 10 sec. interval after occlusion varied from control heart rates in a range of —5 to +5 beats/min. This is a variation of ±3 per cent from the control and is comparable to that observed when no procedure is imposed. Differences in cardiac response to aortic occlusion in vagotomized or sinoaortic denervated animals anesthetized with either morphine-sulfate-chloralose, sodium pentobarbital or morphine-sulfate-ether are not apparent (figs. 1—3).

DISCUSSION

Aortic occlusion in dogs having all neural pathways intact caused a rise in mean arterial pressure ranging from 24 to 66 mm. Hg (average 42) and invariably elicited a reduction in heart rate ranging from 18 to 173 beats/min. lower than the control levels. Following vagotomy the cardioinhibitory response to aortic occlusion was decreased. However, from a comparison of the degree of cardiac slowing elicited by aortic occlusion in the animals anesthetized with sodium pentobarbital (fig. 1) with that elicited in the animals anesthetized with morphine-chloralose (fig. 2), it will be noted that in the former group there is little difference in degree of cardiac inhibition before vagotomy, when slowing may result from an increase in number of cardioinhibitory impulses reaching the heart via the vagi and a decrease in number of cardioaccelerator impulses reaching the heart via the sympathetics (Bronk, Ferguson and Solandt), than after vagotomy when slowing may occur only by depression of cardioaccelerator tonus. In contrast, the group anesthetized with morphine-chloralose showed a much greater degree of cardiac slowing before than after vagotomy. The elevation of mean arterial pressure was approximately the same in both groups and, in nearly every instance, was greater after than before vagotomy (table I). Under the influence of sodium pentobarbital cardiac slowing elicited by a rise in mean arterial pressure appears to occur largely by depression of cardioaccelerator tonus even though the vagal inhibitory mechanism is intact. This may be explained as due to a peripheral blocking effect of sodium pentobarbital on the vagal inhibitory mechanism as demonstrated by Koppanyi et al. Elevation of mean arterial pressure produced by aortic occlusion in vagotomized dogs ranged from 40 to 90 mm. Hg (average 53) and in all but one animal was followed by a reduction in heart rate ranging from 6 to 35 beats/min. lower than the control level. Since there was no depression of cardioaccelerator tonus in any of the sinoaortic denervated dogs following aortic obstruction, it may be concluded that all afferent pathways from receptors of the sinoaortic type located in the vascular tree above the celiac artery had been sectioned.

Pressoreceptors in the cerebral circulation frequently have been postulated. However Heymans and recently Taylor and Page demonstrated that a severe rise in pressure in cerebral vessels of dogs whose cerebral circulation was isolated and perfused elicits no reflex vasodilatation or cardiac inhibition. Schmidt has emphasized the importance of blood flow to the medullary centers in regulating respiration. In studies reported from this laboratory using the same technic to induce aortic occlusion as that employed in these experiments it was observed that delayed respiratory inhibition still persisted in some instances following aortic obstruction in sino-denervated dogs. Activation of the sinoaortic type of pressoreceptors reflexly elicited vasodilatation, cardiac inhibition and decreased respiration. Since no cardiac inhibition can be elicited in sinoaortic denervated dogs in response to aortic occlusion, further evidence is presented that the respiratory inhibition previously observed under these con-
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ditions is on a basis other than a reflex response from the sinoaortic type of pressoreceptors.

Summary

The cardioinhibitory response to occlusion of the descending aorta was elicited in either normally innervated or vagotomized dogs anesthetized with either sodium pentobarbital, morphine sulfate-chloralose or morphine sulfate-ether. Aortic occlusion in sinoaortic denervated dogs which produced a rise in mean arterial pressure greater than and in many cases double that produced in the same animals having all neural pathways intact did not elicit changes in heart rate. Therefore after elimination of the sinoaortic mechanism by vagotomy and isolation of the carotid sinuses no functional pressoreceptors of the sinoaortic type can be demonstrated in the arterial tree above the level of the celiac artery.

Sodium pentobarbital has a blocking action on the vagal component of the cardio-inhibitory response to a rise in blood pressure while leaving intact the depression of cardioaccelerator tonus in response to the same stimulus.

Acknowledgment

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Summario in Interlingua

Le responsa cardioinhibitori a occlusion del aorta descendente esseva studiate in canes con innervation normal e in canes vagotomisate, post lor anesthesiation per pentobarbital de natrium, sulfato de morphia e chloralose, o sulfato de morphia e ethere. Le occlusion aortic effectuate in canes con disnervation sinoaortic produceva un augmento del valor medie del pression arterial per usque a duo vices le correspondente augmento producute in canes in que omne le vias neural esseva intacte, sed illo non resultava in un alteration del frequentia cardiac. Ergo, post le elimination del mechanismo sinoaortic per medio de vagotomia e post le isolation del sinuses carotic, nulle presso-receptores functional del typo sinoaortic pote esser demonstrate in le systema arterial supra le nivello del arteria celiac.

Pentobarbital de natrium exerce un action blocante super le componente vagal in le responsa cardioinhibitori a augmentos del pression de sanguine, durante que illo lassa intacte le depression del tono cardio-acceleratori in responsa al mesme stimulo.

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