Chronic Constriction of the External and Internal Carotid Arteries in Dogs: Its Effect on the Blood Pressure

By PAUL KEZDI, M.D.

NEUROGENIC hypertension can be produced in dogs by denervation of the carotid sinus and disruption of the vago-aortic nerves. This procedure usually results in severe hypertension, the hemodynamics of which were studied by several investigators.1,2 Chronic disruption of the carotid sinus nerves alone, was thought not to effect the blood pressure.3 This was attributed to sufficient buffer action of the remaining baroreceptors.

Walkerlin and co-workers reported that bilateral constriction of the carotid sinus in dogs by plastic clamps resulted in moderate hypertension.4 Although the authors showed that the carotid sinus nerves were inadvertently disrupted by the clamp in most of these animals, they preferred to explain the mechanism of hypertension in their experiments by a change in cerebral hemodynamics rather than by altered carotid sinus function.5 To clarify the problem of carotid sinus participation in this type of hypertension, experiments were devised in which cerebral hemodynamics were altered by constriction of the external and internal carotid arteries with the carotid sinus nerves left intact at first. Denervation of the carotid sinus was performed several months later to elucidate whether hypertension develops before or after disruption of the carotid sinus nerves.

Method

Mongrel dogs were used after a period of 1 to 2 months of control observation of blood pressure. Blood pressure was measured by direct femoral artery puncture and a mercury manometer. Dogs were anesthetized with pentobarbital (26.5 mg./Kg.). The external and internal carotid arteries were carefully isolated to avoid damage to the carotid sinus nerves. A small silver clip was placed about one quarter of an inch above the carotid bifurcation. The arteries were narrowed to approximately one third of their original lumen. The circumference of the arteries was estimated by placing a loop of thread loosely around them. The inner circumference of the clamps was adjusted to about one third of the loop of thread before placing the clamps on the arteries. The occipital artery and most of the other small branches originating at the carotid bifurcation were ligated.

During the same operation both common carotid arteries were explanted in a tube of skin low in the neck. Blood pressure and heart rate were measured postoperatively at weekly intervals for 4 to 8 months. The function of the carotid sinus nerves was tested by occlusion of the common carotids between fingers in the conscious animal each time the blood pressure was measured. In an occasional dog, the carotid sinus nerves were damaged during the first operation or by scar tissue. No carotid reflex was present in these dogs which were discarded for this experiment.

Four to 8 months after the first operation the carotid sinus nerves were cut between ligatures at their junction with the glossopharyngeal nerves. The dogs were then observed for an additional 6 or more months. The dogs were then sacrificed and the carotid arteries were examined for patency. In 3 dogs a plastic material was injected into the common carotid arteries to form a cast of the lumen of the vessels.6 The vessel wall was macerated with saturated KOH. In 2 dogs under pentobarbital anesthesia, arteriograms were obtained by injecting Diodrast into the common carotid arteries.

Results

Effect of Constriction of the External and Internal Carotid Arteries

The average blood pressure before constriction of the external and internal carotid arteries in 10 dogs was 119 mm. Hg, and after operation 121 mm. Hg (table 1). The minimal change was statistically not significant (p > 0.5). The carotid occlusion test, which was performed each time when blood pressure was measured, showed that the carotid sinus nerves were intact in all the dogs during this observation period. The average blood pressure increase following bilateral common ca-
Table 1
Blood Pressure and Response to Bilateral Common Carotid Occlusion in Conscious Dogs Following Narrowing of Internal and External Carotid Arteries and Subsequent Disruption of the Carotid Sinus Nerves

<table>
<thead>
<tr>
<th>Dog no.</th>
<th>Control period Mean BP mm. Hg (range)</th>
<th>After narrowing of int. and ext. carotid arteries Mean BP mm. Hg (range)</th>
<th>Duration Months</th>
<th>Response to bilat. common carotid occlusion Increase of BP mm. Hg</th>
<th>After subsequent disruption of carotid sinus nerves Mean BP mm. Hg (range)</th>
<th>Duration Months</th>
<th>Response to bilat. common carotid occlusion Increase of BP mm. Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>124 (120-130)</td>
<td>115</td>
<td>4</td>
<td>+56</td>
<td>160 (156-160)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>140 (130-140)</td>
<td>143</td>
<td>8</td>
<td>+48</td>
<td>180 (170-190)</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>125 (120-130)</td>
<td>134</td>
<td>6</td>
<td>+32</td>
<td>162 (156-170)</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>126 (108-134)</td>
<td>121</td>
<td>4</td>
<td>+28</td>
<td>140 (136-140)</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>115 (120-120)</td>
<td>115</td>
<td>5</td>
<td>+31</td>
<td>152 (148-156)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>123 (120-120)</td>
<td>126</td>
<td>8</td>
<td>+32</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>110 (105-114)</td>
<td>107</td>
<td>4</td>
<td>+49</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>110 (104-110)</td>
<td>124</td>
<td>4</td>
<td>+31</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>115 (110-120)</td>
<td>120</td>
<td>4</td>
<td>+31</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>102 (90-108)</td>
<td>106</td>
<td>4</td>
<td>+35</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Average</td>
<td>119 (112-125)</td>
<td>121</td>
<td>5</td>
<td>+37</td>
<td>160 (148-175)</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Effect of Bilateral Sinus Denervation

Five of the 10 dogs survived the second operation. As shown in table 1, all 5 developed significant hypertension. The average increase of pressure was from 125 to 160 mm. Hg (p < 0.01). Blood pressure increased gradually in most of the animals and reached its highest level 2 to 6 weeks after the operation. In 1 dog the pressure was increased 1 week after the disruption of the carotid sinus nerves. Heart rate increased in the 5 dogs from 101 to 107 per minute. The change was statistically not significant (p > 0.5).

The plastic cast of the carotid arteries in 3 dogs and dissection and probing of the arteries in the rest of the animals showed that the postconstricted segment of the external carotid was patent in all 10. In 2 dogs, the internal carotid arteries were occluded bilaterally, in 1 unilaterally, at the site of the clip, while in 7 they were patent. An arteriogram of the carotid arteries in 1 of the dogs is shown in figure 2.

Discussion

Bilateral constriction of the internal and external carotid arteries with the carotid sinus nerves left intact did not lead to significant change in blood pressure in the dog. The clamps produced a narrowing of the arteries similar to that produced by a Goldblatt clamp on the renal artery. It is unlikely that ischemia to the brain can be produced by narrowing of the external and internal carotid arteries, since dogs have well developed vertebral arteries and good intracranial communications between the vertebral and carotid artery branches. But even if ischemia or al-
tered cerebral hemodynamics was produced by narrowing of the external and internal carotid arteries, it did not result in hypertension in our experiments.

Later disruption of the carotid sinus nerves, on the other hand, consistently resulted in mild to moderate hypertension. It seems likely, therefore, that in the experiments of Crandall and co-workers the inadvertent disruption of the carotid sinus nerves and possibly damage to other buffer nerves could have been responsible for hypertension. Koch also found in an occasional dog that moderate hypertension developed following disruption of the carotid sinus nerves alone. However, he observed the dogs for only a relatively short time.

There is a marked increase of the heart rate in dogs in which all 4 buffer nerves were disrupted even with meticulous care to disrupt only the vago-sympathetic nerves and spare the cardiac vagus. Tachycardia is one of the characteristics of neurogenic hypertension. However, the resting heart rate did not change significantly in our carotid sinus hypertensive dogs although it was observed that excitement seemed to produce more marked tachycardia than before carotid denervation. A normal heart rate therefore should not be used as an argument against carotid sinus participation in the carotid sinus constricted dogs of Crandall and co-workers.

It seems strange that hypertension develops after a latent period following disruption of the carotid sinus nerves. Thomas observed that complete debuffering by stepwise disruption of the 4 buffer nerves resulted in gradual blood pressure increase. The highest level was not reached for several weeks after the disruption of the last buffer nerve. There is no good explanation for this latent period. The explanation of Heymans and Neil that mesenteric baroreceptors step in until they are overpowered is at best speculative.

Experiments of Hawthorne and Gaspar showed that hypophysectomy lowered the blood pressure in carotid sinus constricted animals. They theorized that the pituitary-adrenal system was in some way altered by change of cerebral hemodynamics in dogs with constriction of the carotid sinus. They believed that such alteration of the pituitary-adrenal system could participate in the mechanism of this type of hypertension. However, Bekaert showed that hypophysectomy also reduced the neurogenic hypertension of com-

**Figure 1**
Response to bilateral common carotid occlusion (1, 2, 3, 4) in dog no. 2 with external and internal carotid arteries constricted. No response to occlusion after disruption of carotid sinus nerves (5). Occlusion tests performed in the conscious animal.

**Figure 2**
Carotid angiogram showing clamp narrowing external and internal carotids at arrows. Right internal carotid is only partially filled.
CONSTRUCTION OF CAROTID ARTERIES

pletely debuffered dogs. Following hypophysectomy, probably such a degree of adrenal cortical insufficiency develops, that it results in a decrease of hypertension irrespective of its etiology. Decrease of hypertension following hypophysectomy is probably, therefore, not good evidence for participation of the pituitary in the mechanism of hypertension.

Summary
Narrowing of the internal and external carotid arteries by a clamp does not lead to hypertension if the carotid sinus nerves remain intact. Subsequent disruption of the carotid sinus nerves results in hypertension. It is concluded that the cause of the chronic hypertension in dogs with constriction of the carotid sinus is not due to altered cerebral hemodynamics, but rather to disruption of the carotid sinus nerves.

Summario in Interlingua
Le constriction du interne e exterior arteria carotic per medio de un crampa non resulta in hypertension si le nervos del sino carotic remane intacte. Le subsequente disruption del nervos del sino carotic resulta in hypertension. Es concluidite que le causa del hypertension chronic in canes con constriction del sino carotic non resulta del alterato hemodynamica cerebral sed plus tosto del disruption del nervos del sino carotic.

References
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