Reflex Changes on the Pulmonary and Systemic Pressures Elicited by Stimulation of Baroreceptors in the Pulmonary Artery

By Jose Osorio, M.D., and Mauricio Russek, D.Sc. (Biol.)

The action of sympathetic and parasympathetic nerves on the pulmonary vessels is well known. However, until recently, it was thought that the circulation of blood in the lungs was achieved passively. Anatomical and pathological studies have shown that in cases of pulmonary hypertension there is a marked hypertrophy of the muscular coat of the pulmonary artery, which suggests an active vasoconstriction. Moreover, pressoreceptor-like structures were recently described in the pulmonary arteries, and Coleridge recorded impulses from some vagal fibers when the large branches of the pulmonary artery were distended.

The present work was carried out in order to study the possibility of a pulmo-pulmonary baroreceptor reflex mechanism in the regulation of the pulmonary circulation.

Methods

Experiments were performed on 20 adult mongrel dogs, of either sex, weighing from 8 to 22 Kg., anesthetized with 35 mg./Kg. pentobarbital (Nembutal). The trachea was either cannulated or intubated. A thoracotomy was carried out on the left side, at the level of the fourth intercostal space. The animals were held under artificial respiration by means of a positive-negative pressure pump at 19 to 30/min., as required to inhibit completely the respiratory movements. Polyethylene tubes were placed in the pulmonary and femoral arteries to record blood pressures. Systemic pressure was recorded with a mercury manometer. Pulmonary arterial pressure was recorded with a membrane manometer in some experiments and with a water manometer in others; the second device was more satisfactory. The dogs were heparinized with 1 to 2 mg./Kg.

A balloon or a "cuffed cylinder" (fig. 1) was introduced into the pulmonary artery through either a lobular branch or the right ventricle. In some experiments, all the pulmonary tissue distal to the place of entrance was resected. In some others, one of the lungs was denervated by denuding the entire hilum.

Results

When a balloon was inflated in a branch of the pulmonary artery (P.A.) the pulmonary arterial pressure (P.A.P.) increased notably (table 1, fig. 2). At first, it was thought that this change was due to the occlusion of the vascular field peripheral to the balloon, but this was shown not to be the case.

The suppression of a whole lung from the circulation without distention of the pulmonary artery (starch injection), or the inflation of a balloon in an artery of a completely denuded hilum, or the clamping of an entire hilum with sufficient pressure to block the nerve fibers, produced only a negligible increase in P.A.P. (table 2, fig. 3). Moreover, the inflation of a "cuff" (fig. 1), which distended the artery without occluding the circulation, produced a P.A.P. increase of the same magnitude as the balloon (table 1, fig. 3). Therefore, it seems that the increase in flow through one lung, resulting from the elimination of the vascular field of the other, is immediately compensated for and does not produce a rise in P.A.P. On the contrary, the distention of the P.A. wall in a normally innervated lung is sufficient to produce an important rise in P.A.P., usually maintained for the entire duration of the stimulus or even longer (fig. 3).

This pulmonary hypertension was usually accompanied by a systemic hypotension. No cardiac frequency changes were observed during these reactions (table 1), but sometimes extrasystoles were produced (fig. 2).

There was no correlation between the changes in pulmonary and systemic pressures.
Sometimes a strong pulmonary hypertension was obtained with a small or nonexistent systemic hypotension; on other occasions, a strong systemic hypotension was obtained with small or negligible changes in P.A.P.

It was interesting to observe that, when a balloon was inflated in the arterial branch of a normal lung and the hilum of the other lung was denudated, the P.A.P. increased, just the same as when both lungs were normally innervated. In the same preparation, the inflation of the balloon in the artery of the denuded hilum did not produce any change in P.A.P.

The hypoxia, brought about by either arresting the respiratory pump or intravenous injection of sodium cyanide (0.2 mg./Kg.), seemed to potentiate the pulmonary hypertension and the systemic hypotension produced by P.A. distention (fig. 3). Hypoxia (of either kind) in itself, usually produced strong pulmonary and systemic hypertension (table 3). The local application of sodium cyanide solution in the surface of the lung did not produce any effect. The section of both vagi did not eliminate the pulmonary hypertension produced by P.A. distention.

Discussion

The evidence presented above suggested that the increase in pulmonary arterial pressure is a reflex originated from baroreceptors localized in the large branches of the pulmonary artery. The afferent fibers seem to lie in the adventitia of the structures of the hilum, but the efferents might belong to the nerve fibers of the muscular layer.8 This explanation is partly based on the observation that demudation of all the structures in the hilum eliminated the afferent component but did not interfere with the effector response. Neither the afferent nor the effector fibers of this response seem to belong to the vagus nerve.

The potentiation of both pulmonary hypertension and systemic hypotension by hypoxia is similar to the potentiation of the depressor nerve bradycardic response.9

The pulmonary hypertension was obtained by distention of those same places where Coleridge7 had observed baroreceptor activity.

### TABLE 1

**Effects of Pulmonary Artery Distention**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Response</th>
<th>Percent</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulmonary pressure</strong></td>
<td>29 mm.</td>
<td>+7 mm.</td>
<td>27</td>
<td>42</td>
</tr>
<tr>
<td>(membrane manometer)</td>
<td>90 mm.</td>
<td>+8.5 mm.</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>Water manometer</td>
<td>29</td>
<td>+7.0 mm.</td>
<td>34</td>
<td>13</td>
</tr>
<tr>
<td>(water manometer)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Systemic pressure</strong></td>
<td>0 mm.</td>
<td>-18</td>
<td>-20</td>
<td>56</td>
</tr>
<tr>
<td>(mm. Hg)</td>
<td>90</td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td><strong>Cardiac frequency</strong></td>
<td>132</td>
<td>+2.4</td>
<td>+1.8</td>
<td>19</td>
</tr>
<tr>
<td>(per minute)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pulmonary and systemic pressure change elicited by the inflation of a balloon in a large branch of the pulmonary artery. Notice the extrasystoles in the right-hand kymogram.

**FIGURE 2**

Pulmonary and systemic pressure changes elicited by distention of a large branch of the pulmonary artery with a "cuffed cylinder" (upper kymogram). Same during hypoxia (lower right). Clamping of an entire hilum with sufficient pressure to block nerve fibers (lower left).

**FIGURE 3**

Table 2

<table>
<thead>
<tr>
<th>Change in Pulmonary Arterial Pressure</th>
<th>Response (cm. water)</th>
<th>Per cent</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch injection (one lung)</td>
<td>+0.9</td>
<td>+3.0</td>
<td>10</td>
</tr>
<tr>
<td>Balloon in artery of denudedated hilum</td>
<td>+0.7</td>
<td>+2.5</td>
<td>4</td>
</tr>
<tr>
<td>Clamping of hilum</td>
<td>+1.1</td>
<td>+3.8</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>Effect of Hypoxia on Pulmonary and Systemic Arterial Pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response of pulmonary arterial pressure (cm. water)</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>Pump arrest</td>
</tr>
<tr>
<td>Cyanide</td>
</tr>
</tbody>
</table>

(Bifurcation of main P.A., large P.A. branches). This author observed impulses going through some vagal fibers. As the vagus nerve is not essential for the production of the pulmonary hypertension, there must be other baroreceptor fibers from the same regions of the P.A. traveling through other nervous pathways. Schwiegk found that the increase of pressure in the pulmonary artery after ligation of the pulmonary veins, produced bradycardia and systemic hypotension. Schweitzer, observed in 2 of 12 cats a fall in the systemic pressure, when the veins of one lung were ligated and the corresponding pulmonary pressure was elevated. This variability in the systemic pressure changes was also observed in the present study.

On the other hand, Lewin at al. observed mild increase in the systemic pressure when the pulmonary artery, isolated from the circulation, was distended by a pressure of 400 mm. Hg. A similar reaction was obtained on one dog in this work. It would seem that stronger distention of the P.A. tended to produce systemic hypertension, while a weaker one would produce hypotension or have no effect whatsoever.

The pulmonary hypertension obtained with cyanide injection or pump arrest was similar to that reported by de Burgh Daly and de Burgh Daly. There is evidence that all the effects of cyanide, at these dosages, may be attributed to chemoreflex mechanisms and not to a direct effect upon the tissues.

Taquin and Aviado observed that the partial occlusion of the main pulmonary artery produces an increase in pulmonary blood flow.
of cardiac origin, accompanied by a rise, a fall, or no change of the pulmonary pressure peripheral to the partial ligature. Perhaps this variability in the changes of P.A.P. can be explained by the predominance in some occasions of the reflex hypertension described in the present paper. The ligature would stimulate the receptors in the P.A., while this reflex would be absent, when the receptor fibers would be blocked or destroyed by a stronger pressure of the ligature.

In conclusion, the results of the present work, suggest the existence of a pulmo-pulmonary baroreceptor reflex, originating in the large pulmonary branches, the afferent fibers of which seem to lie in the adventitia. Its stimulation, by distention of the artery, elicits a pulmonary hypertension together with a variable systemic hypotension. The effector fibers of the pulmonary hypertension do not run in the adventitia. Neither afferent nor efferent fibers belong to the vagus.

Summary
The distention of a large branch of the pulmonary artery, with or without occlusion of the circulation, produces pulmonary hypertension. The occlusion of an entire hilum, without adequate stimulation of the arterial baroreceptors produces only a negligible increase in pulmonary arterial pressure. Together with the pulmonary hypertension, variable changes in the systemic pressure were observed. The most frequent reaction was hypotension. The vagal fibers play no role in the pulmonary hypertensive response.

Acknowledgment
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References
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