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THE EFFECTS OF STIMULATION OF THE CAROTID SINUS BARORECEPTORS ON THE PULMONARY VASCULAR BED IN THE DOG

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Daly & Daly (1957) found that stimulation of the carotid sinus baroreceptors by raising the carotid sinus pressure caused an increase in pulmonary vascular resistance, indicated by an increase in the pressure gradient across the pulmonary vascular bed at constant pulmonary arterial blood flow. They expressed the view that because this effect occurred after denervation of the lungs it was passive to the accompanying reflex fall in systemic blood pressure, giving rise to a redistribution of blood between the bronchial and pulmonary vascular systems (Berry & I. de B. Daly, 1931). They mentioned, however, that their experiments did not exclude the possibility of a direct reflex from the carotid baroreceptors on the pulmonary vascular bed proper, the existence of which could only be demonstrated unequivocally in a preparation in which it was possible to interrupt temporarily the blood flow through the bronchial circulation while tests of stimulation of the carotid sinus baroreceptors were carried out. The 'vasosensory controlled perfused living animal' preparation (Daly & Daly, 1959) meets not only this requirement but others necessary to control all known mechanisms which passively affect the pulmonary vascular resistance (I. de B. Daly, 1956). We have carried out experiments using this preparation, and in this paper evidence is presented that the pulmonary vascular bed proper is under reflex control from the carotid sinus baroreceptors.

METHODS

The results were obtained from the experiments described by Daly & Daly (1959). Dogs varying in weight from 10·8 to 15·5 kg were anaesthetized with chloralose (0·1 g/kg intravenously) after premedication with morphine hydrochloride (1 mg/kg subcutaneously). The method of simultaneous and separate perfusion of the vasosensory areas of the carotid bifurcations and of the

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aortic arch, of the cerebral circulation, the vascular bed of the descending thoracic aorta and the pulmonary circulation, was the same as that described previously (Daly & Daly, 1959).

Carotid baroreceptor reflexes were elicited by altering the mean pressure in the isolated perfused carotid sinuses. These changes in pressure were brought about by altering the pressure applied to the Starling resistance situated on the outflow side of the carotid sinuses. The baroreceptors in the isolated aortic arch were stimulated by raising the intra-aortic pressure (Daly & Daly, 1959).

TABLE 1. The effects of stimulation of the carotid sinus baroreceptors on pulmonary vascular resistance with and without the circulation of blood through the bronchial vascular system

Expt. No.	Bronchial circulation intact	Zero bronchial arterial B.P.
1	–	0
2	–	–
3	–	–*, §
6	–	.
7	–	–§
9	–	–
12	–	.

–, 0 = decrease and no change in pulmonary vascular resistance, respectively. * In atropinized and vagotomized preparation. § Abolished by stellectomy.

RESULTS

It was found in seven experiments that when stimulation of the carotid sinus baroreceptors, by raising the mean carotid sinus pressure, was carried out whilst blood was circulating through the bronchial vascular system, a fall in pulmonary arterial perfusion pressure invariably occurred. This fall in pulmonary arterial pressure occurred under conditions in which the pulmonary circulation was perfused at a constant blood volume inflow and at a constant left auricular pressure, and was therefore interpreted as a reduction in pulmonary vascular resistance (Table 1 and Figs. 1*A*, 2*A*, 2*D*). These changes occurred independently of variations in lung 'hindrance'.

The tests were then repeated during temporary interruption of the blood circulating through the bronchial vascular bed, to exclude the participation of passive effects on the pulmonary circulation proper due to changes in the bronchial circulation. In four out of five experiments in which this test was carried out at zero bronchial arterial pressure, a reduction in pulmonary vascular resistance was still obtained in response to carotid sinus distension. In the fifth experiment, the response was suppressed (Expt. 1 in Table 1, Fig. 2*C*). The typical response is shown in Fig. 1*B*. The reduction in pulmonary arterial perfusion pressure after carotid sinus distension which occurred at zero bronchial arterial pressure cannot be attributed to changes in cerebral perfusion pressure, since this pressure was compensated during this test. Nor can the response be secondary to changes in aortic arch pressure which normally occur on stimulation of the carotid baroreceptors, because in this experiment the aorta was isolated and the pressure maintained constant. From these

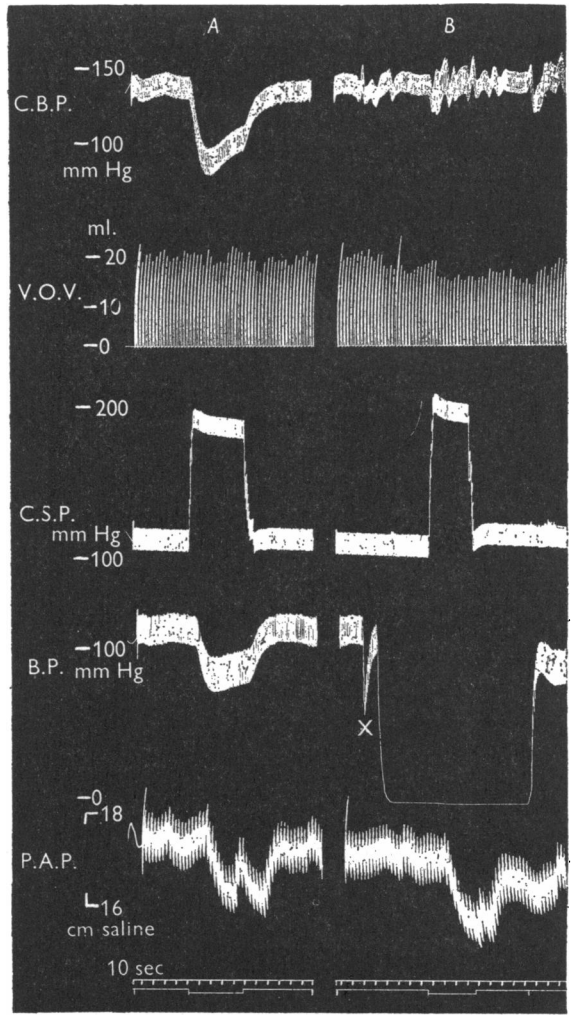

Fig. 1. Dog, ♀, 14·0 kg. Morphine-chloralose. 'Vasosensory controlled perfused living animal' preparation. Pressure in the isolated aortic arch maintained constant at 70 mm Hg. In *A* and *B*, the mean pressure in the isolated perfused carotid sinuses was temporarily raised. In *B*, the test was made after switching off the pump perfusing the vascular bed of the thoracic aorta beyond the origin of the left subclavian artery so as to reduce the bronchial arterial pressure to zero. The cerebral blood pressure was maintained constant by adjustments to the output of the 'cerebral' perfusion pump. *X*, artifact. In this and in Fig. 2: C.B.P., cerebral blood pressure; V.O.V., ventilation overflow volume; C.S.P., carotid sinus pressure; B.P., femoral arterial blood pressure; P.A.P., pulmonary arterial pressure.

results we conclude that stimulation of the carotid sinus baroreceptors causes a reflex dilatation of the pulmonary vascular bed proper.

In one experiment the reflex pulmonary vasodilator response, which occurred at zero bronchial arterial pressure in response to raising the carotid sinus pressure, persisted after atropine and after division of the cervical vago-sympathetic nerves; it was abolished, however, by destruction of the stellate ganglia. In one further experiment stellectomy also abolished this reflex. From these experiments it is concluded that the reflex is mediated through the upper thoracic sympathetic outflow.

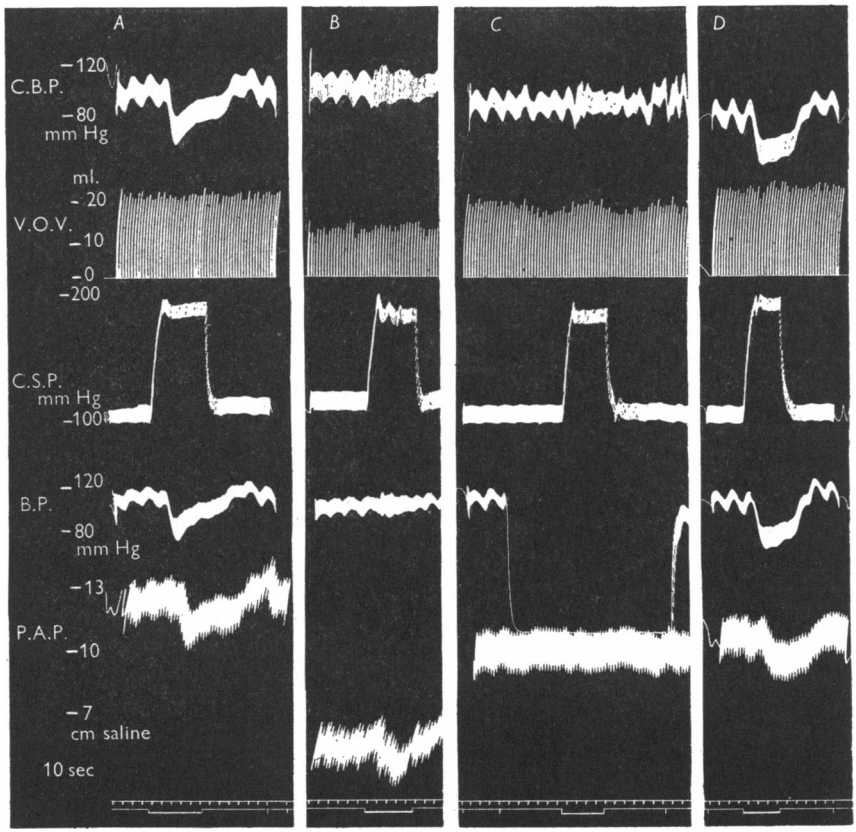

Fig. 2. Dog, ♀, 10·8 kg. Morphine-chloralose. 'Vasosensory controlled perfused living animal' preparation. Aortic arch included in cerebral perfusion system (Daly & Daly, 1959, Fig. 2*A*). *A*, *B*, *C* and *D* show the effects of temporarily raising the mean carotid sinus perfusion pressure. In *A* and *D*, the pressures in the aortic arch, cerebral circulation and in the vascular bed of the thoracic aorta beyond the origin of the left subclavian artery were uncompensated. In *B*, they were maintained constant by adjustments to the output of the pumps. In *C*, the test was made at zero bronchial arterial pressure, i.e. while the pump perfusing the vascular bed of the descending thoracic aorta was switched off. The cerebral and aortic arch blood pressures were maintained constant.

Bronchial vasomotor reflexes

The possibility of the existence of reflex bronchial vasomotor activity has been referred to in our previous paper (Daly & Daly, 1959). In one of the experiments described above (Fig. 2*C*) we obtained no evidence for a reflex effect on the pulmonary vascular bed proper, yet when blood was flowing through the bronchial circulation raising the carotid sinus pressure caused a reduction in pulmonary vascular resistance. This suggests that the reduction in pulmonary vascular resistance was passive to changes in the bronchial vascular system and could have been due to the fall in systemic (bronchial) arterial pressure resulting from systemic vasodilatation and/or changes in the resistance of the bronchial arterioles. It was shown, however, that the response still occurred when the expected fall in both cerebral and systemic perfusion pressures were compensated during the test (compare *A* and *D* with *B* in Fig. 2). This means that the reduction in pulmonary vascular resistance could not have been secondary to a change in bronchial arterial pressure, and the most likely explanation is that it was secondary to a reflex change in bronchial vascular resistance.

Effects of stimulation of the aortic baroreceptors

In one experiment the aortic baroreceptors were stimulated by raising the mean pressure in the isolated aortic arch. This resulted in a fall in systemic and cerebral blood pressures and a reduction in pulmonary vascular resistance. This latter response persisted when the test was repeated at zero bronchial arterial pressure and is therefore the result of a reflex dilatation of the pulmonary vascular bed proper. This reflex was abolished by bilateral stellectomy. It should be mentioned that the consistent reflex vasodilatation of the pulmonary vascular bed proper to stimulation of the carotid sinus and aortic arch baroreceptors occurred under the varying conditions of arterial blood pO_2, pCO_2 and pH which have been described in the preceding paper (Daly & Daly, 1959).

DISCUSSION

In a previous paper (Daly & Daly, 1957) it was found that when blood was circulating through the bronchial vascular system, stimulation of the carotid sinus baroreceptors caused an increase, or more rarely a decrease, in pulmonary vascular resistance. These responses were not the result of a direct nervous effect on either the bronchial or pulmonary vascular systems because they persisted after denervation of the lungs. It was suggested that the increase in pulmonary vascular resistance was passive to the reflex fall in systemic (bronchial) arterial pressure by causing a redistribution of blood between the greater and lesser circulations via the intrapulmonary

communicating channels of these two systems. On the other hand, in the present experiments when blood was circulating through the bronchial vascular system we consistently observed a reduction in pulmonary vascular resistance associated with the reflex fall in systemic (bronchial) arterial pressure on stimulating either the carotid sinus or the aortic baroreceptors. Furthermore, after denervation of the lungs, imposed changes in systemic (bronchial) arterial pressure caused small and inconsistent changes in pulmonary vascular resistance. It would appear therefore that there is a fundamental difference between the type of preparation used by Daly & Daly (1957) and the 'vasosensory controlled perfused living animal' preparation, in respect of the passive effects on the pulmonary vascular resistance produced by changes in systemic (bronchial) arterial pressure. This recalls a statement made by Berry & I. de B. Daly (1931) that they were 'unable to correlate the type of pulmonary arterial response to changes in aortic or bronchial arterial pressure with any of our experimental conditions'. Their experiments were performed on isolated lung preparations perfused through the pulmonary and bronchial circulations. A comparison of the present experiments with those of Daly & Daly (1957) reveals a similar state of affairs.

Notwithstanding these obscure mechanisms which control the *passive* effects of the bronchial circulation on the pulmonary vascular resistance, our experiments clearly reveal that when these passive effects, and indeed all other known passive effects on the pulmonary vascular bed, are excluded, stimulation of the baroreceptors in the carotid sinus and aortic arch causes a reflex vasodilatation of the pulmonary blood vessels themselves. The implications of these results are of considerable interest in that they suggest that tonic sympathetic nerve impulses normally exert an influence on some part of the pulmonary vascular bed proper, and that these can be modified reflexly through the carotid sinus and aortic arch baroreceptors.

SUMMARY

1. In the 'vasosensory controlled perfused living animal' preparation in which the regions of the carotid bifurcations and aortic arch, the brain, the remainder of the systemic circulation and the lungs were separately perfused, the carotid sinus baroreceptors were stimulated by raising the carotid sinus pressure.

2. It was found that when blood was flowing through the bronchial vascular system, carotid sinus distension caused a reduction in pulmonary vascular resistance, indicated by the change in the pressure gradient across the pulmonary vascular bed at constant pulmonary arterial blood flow.

3. When the test was repeated during temporary interruption of the blood flow through the bronchial circulation, the reduction in pulmonary vascular resistance still occurred.

4. This response occurred independently of changes in lung 'hindrance', in left auricular pressure and in the pressure in other parts of the systemic circulation, but was abolished by bilateral stellectomy.

5. It is concluded that stimulation of the carotid sinus baroreceptors causes a primary reflex dilatation of the pulmonary vascular bed proper due to inhibition of sympathetic vasoconstrictor tone.

6. Evidence is presented suggesting that carotid sinus baroreceptors reflexly control the bronchial vascular system.

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