PHYSIOLOGY

Dynamic Relationships between Catecholamine-Induced Shifts of Pressure and Blood Flow in Pulmonary Artery

B. I. Tkachenko, V. I. Evlakhov, and I. Z. Poyassov

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Experiments on cats showed that catecholamines produced maximum changes in pulmonary artery blood pressure during 12-16 sec postinjection, while blood flow in this artery attained maximum only to 40 sec postinjection, *i.e.* changes in blood flow attained maximum and ended later than blood pressure shifts. Intravenous epinephrine produced bidirectional changes in blood pressure, while norepinephrine always elevated blood pressure in the pulmonary artery; pulmonary circulation increased after injection of both catecholamines.

Key Words: *pulmonary hemodynamic; blood pressure; blood flow; epinephrine; norepinephrine*

Published data on the character and degree of the shifts in the parameters of pulmonary hemodynamics induced by catecholamines (CA) are contradictory [1,7,8]. Epinephrine can either increase or decrease blood pressure in the pulmonary artery (PABP), while norepinephrine always elevates it [1,9]. Both CA increase blood flow in the pulmonary artery (PABF) [1,6,9]. Clinical measurements of PABF in humans are usually discontinuous [1,8] and provide no information on its dynamics during the action of CA on the cardiovascular system. Temporal relationships between the shifts in PABF and PABP were not studied on experimental animals.

Our aim was to study dynamic relationships between PABF and PABP and their quantitative shifts during the effect of intravenous CA.

MATERIALS AND METHODS

Experiments were carried out on cats weighing 3.5-5.0 kg (n=23) anesthetized with sodium pentobarbital (35-40 mg/kg intramuscularly). The thorax was opened, and the cats were artificially ventilated with a Faza-9 apparatus. The gas composition of arterial and venous blood was analyzed using an ABL-3 gas analyzer (Radiometer). Blood pressure in the left femoral artery was recorded with a PDP-400 pressure transducer. PABF was measured with a cuff transducer coupled to a T-106 ultrasonic flowmeter (Transonic). PABP was recorded with a PDP-400 pressure transducer coupled to a fine elastic catheter 2 mm in diameter introduced into the pulmonary artery via the right atrial auricle and right ventricle (through the tricuspid and semilunar valves). This catheterization procedure is similar to manipulations with pulmonary artery in human patients.

Pulmonary vascular resistance was calculated using Poiseuille formula by dividing the difference between the mean PABP and pressure in the left atrium by PABF [1]. Pressure in the left atrium was measured with a Baxter pressure transducer and a catheter introduced into the cavity of the left atrium via the auricle. The mean values of PABP and pressure in the left atrium were calculated from the recorded maximum and minimal values. HR was

Department of Visceral Systems Physiology, Institute of Experimental Medicine, Russian Academy of Medical Sciences, St. Petersburg. ***Address for correspondence:*** viespbru@mail.ru. V. I. Evlakhov

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measured with a tachometer by *RR*-interval of ECG recorded in standard lead II. Bolus of CA (epinephrine or norepinephrine in a dose of 2.5 mg/kg) was injected into the left femoral vein.

The values of PABP, PABF, and left atrial pressure were documented on an H-338-8P pen recorder.

The data were analyzed statistically using Student's *t* test.

RESULTS

Initially, arterial pressure was 87±6 mm Hg, while the values of PABP, PABF, and HR were 28±2 mm Hg, 220±18 ml/min, and 168±4 min^{-1}, respectively.

In all cats, CA increased arterial pressure by about 50% from the initial value. However, CA produced various shifts in PABP of ambiguous character. In 70% experiments, intravenous injection of epinephrine increased PABP by 17±4% (Fig. 1, *a*), the maximum effect being observed on the 16th sec postinjection. By contrast, in 30% cats this parameter decreased by 10±3% (Fig. 2), and the maximum changes were observed on the 20th sec postinjection. Injection of norepinephrine increased PABP in all cats, but the increment and the peak time varied. In half experiments, the maximum increment (26±5%) was observed on the 12th sec (Fig. 1, *b*), while in other cases, the maximum of PABP increment was only 11±4% observed on the 20th sec (Fig. 2).

Since the directivity, amplitude, and peak time of PABP changes induced by CA were different, the data were subdivided into two groups. In group 1 cats, CA increased PABP (the response to epinephrine was less pronounced than that to norepinephrine). In group 2 cats, epinephrine decreased PABP, while norepinephrine increased it, although this increase was less pronounced than in group 1 cats. In group 1 cats, the maximum changes in PABP were observed on 12-16 sec postinjection, *i.e.* they occurred earlier than in group 2 cats (20 sec). In both groups, this parameter returned to initial level on 180-200 sec postinjection.

In group 1 cats, CA increased PABF, but the maximum effect developed by the 40th second only, *i.e.* later than the maximum changes in PABF (12-16 sec). Moreover, PABF returned to the initial level only after 300-320 sec, so its time course was longer than that of PABP changes. In this group, the maximum increments in PABF produced by intravenous epinephrine and norepinephrine were 31±4 and 21±2%, respectively (Fig. 1). At the moment of maximum PABF rise, the increments in PABP produced by epinephrine and norepinephrine were 13±3 and 16±3%, respectively, which means, that in this period, PABP changes were below the maximum (17±4 and 26±5%, respectively).

At the period of maximum PABP shifts, the increments in PABF produced by epinephrine and norepinephrine were 29±4 and 10±2%, respectively (Fig. 1). Therefore, in group 1 cats, epinephrine produced more pronounced shifts in PABF than norepinephrine.

Similar to group 1 cats, CA increased PABF in group 2 cats, although the maximum effect was observed after 20 sec, which corresponded to the time when CA produced maximum changes in PABP. As in group 1 cats, the second group cats demonstrated more prolonged shifts in pulmonary circulation (300-320 sec) in comparison with those of PABP (180-200 sec). The maximum increments in PABF produced by epinephrine and norepinephrine

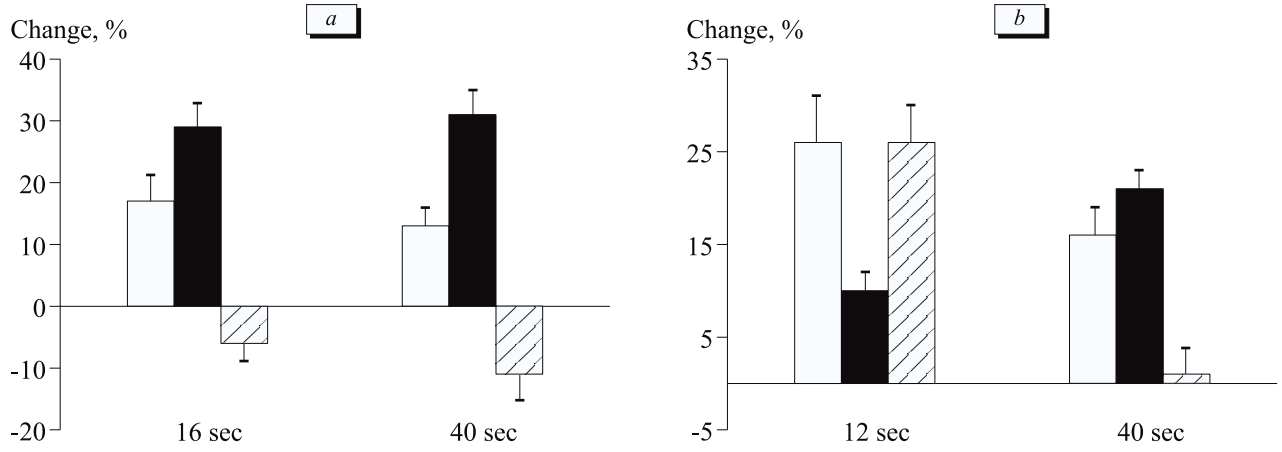

Fig. 1. Directivity and magnitude of changes in parameters of pulmonary hemodynamic induced by intravenous injection of CA in group 1 cats. Here and in Fig. 2: *a*) injection of epinephrine in a dose of 2.5 μg/kg; *b*) injection of norepinephrine in a dose of 2.5 μg/kg. Open, closed, and the dashed bars show PABP, PABF, and PVR, respectively.

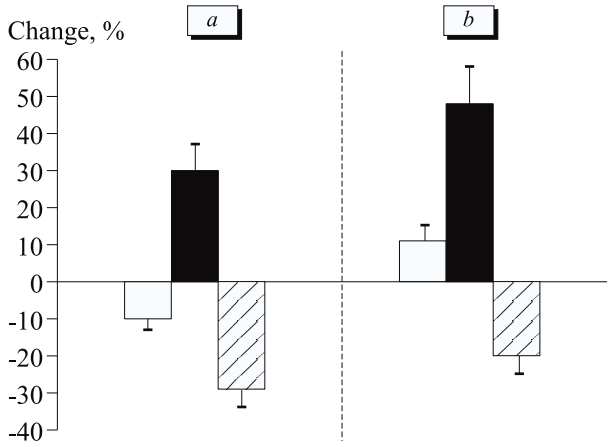

Fig. 2. Effects of CA on parameters of pulmonary hemodynamic in group 2 cats.

were 30±7 and 48±10%, respectively (thus, norepinephrine was more efficient in increasing pulmonary blood flow than epinephrine, Fig. 2). Therefore, PABF shifts produced by CA were reciprocal in both groups. In group 1, epinephrine produced greater increment in PABF than norepinephrine.

Thus, our study showed that CA increased PABF in all cats. However, in group 1 cats, the pronounced increment of PABP was accompanied by differences in the time courses of changes in PABF and PABP. The maximum increment of PABF in these cats was observed later than that of PABP. In group 2 cats characterized by opposite or minor shifts in PABP in response to epinephrine or norepinephrine, the peak times of PABF and PABP coincided. At the same time, in all experiments changes in PABF were longer than in PABP. It can be hypothesized that the time (phase) shift between PABF and PABP changes produced by CA indicates various degree of changes in resistive and possibly capacitive functions of blood vessels under these conditions [3,6,10]. To verify this assumption, we analyzed changes in calculated vascular resistance.

Initially, pulmonary vascular resistance (PVR) was 132±6 dyn×sec×cm^{-5} in all cats. In group 1 cats, epinephrine decreased PVR by 6±3 and 11±4% to 16 and 40 sec postinjection, respectively, compared to the initial level (Fig. 1, *a*). By contrast, norepinephrine increased PVR, and its maximum increase (26±4%) was observed on 12 sec postinjection. To the 40th sec postinjection, PVR returned virtually to the initial level (the remaining shift by 1±3% was insignificant, Fig. 1, *b*). Therefore, although both intravenous CA increased PABP in group 1 cats, they produced opposite effects on PVR: epinephrine decreased PVR, while norepinephrine increased it. In group 2 cats, both CA decreased PVR after 20 sec by 29±5 and 20±5%, respectively (the effects were similar), although epinephrine decreased PABP, while norepinephrine increased it (Fig. 2).

Thus, the directivity of the shifts in PVR in both groups did not coincide with the character of PABP changes in response to CA. Moreover, in all cats the opposite shifts in PVR caused by CA were observed during the growth of PABF (Figs 1 and 2). This can be explained by the fact, that calculated value of PVR is not only affected by physical hydraulic resistance of pulmonary vessels, but also by other indirect factors such as blood pressure in the left atrium, which in its turn depends on contractile activity of the myocardium [1,3-5]. Thus, our analysis of CA-induced shifts in PVR showed that they did not correlate with those of PABF and PABP, and therefore they cannot be the cause of the observed differences in the time course of these parameters.

We previously demonstrated that in case of intravenous injection of CA, the maximum changes in the right atrial pressure also occurred within 12-16 sec postinjection, while maximum changes in the venous return were observed after 40 sec [2]. Thus, the peak times of PABP and PABF elevations coincided with those of the right atrial pressure and venous return, respectively. Comparison of these data indicates interrelations between PABP and right atrial pressure, on the one hand, and between PABF and venous return, on the other.

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