PHYSIOLOGY

Dynamics of Nitroglycerin-Induced Changes in Vena Cava Flows and Right Atrial Pressure

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In anesthetized cats, nitroglycerin increased blood flow in the superior vena cava and decreased the flow in the inferior vena cava and total venous return. Simultaneous changes in right atrial pressure could be either positive or negative. The shifts in the superior vena cava flow and right atrial pressure preceded the corresponding alterations in the inferior vena cava flow and venous return.

Key Words: *nitroglycerin; the superior and inferior vena cava flows; venous return; right-atrial pressure; arterial blood pressure*

Despite wide use of nitroglycerine in cardiological practice, there are conflicting data about its effects on venous return and blood flow in the venae cavae. It is accepted [6-8] that nitroglycerine via stimulation of NO production in smooth muscle cells produces a direct vasodilating effect and reduces venous return [3,4]. However, an increase in total venous return in dogs in response to nitroglycerine was reported [5]. Intravenous infusion of nitroglycerine decreasing venous return induced a noticeable decrease in right atrial pressure [6,8]. Nitroglycerin induces transcranial shunting of the common carotid arterial flow to cranial veins via the superficial cranial arteriovenous bypasses [3,4] resulting in overdistension of intracranial veins and reduction of blood flow in the superior vena cava [7]. There are no experimental data on the relationships between the dynamics of cava flow and venous return, on the one hand, and shifts in right atrial pressure (RAP) agaist the background of nitroglycerin treatment. Thus, our aim was to study the temporal and quantitative characteristics of nitroglycerin-induced changes in blood flows through the superior and inferior venae cavae, total venous return, and right atrial pressure.

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MATERIALS AND METHODS

The study was performed on 13 artificially ventilated open-chest cats (3.5-5.0 kg body weight) anesthetized with Nembutal (35-40 mg/kg, intramuscularly). Blood pressure (BP) was measured in the left femoral artery with a transducer constructed on the basis of an ultraminiature mechanotron [2]. Blood flows in the superior and inferior venae cavae were measured with a T-230 Transonic dual-channel ultrasonic cuff gage flowmeter. Venous return was calculated as the sum of these flows. RAP was measured with a low-pressure transducer incorporating mechanotron [2] via a catheter introduced into the right atrium through the auricle. Systolic and diastolic RAP were recorded and the mean RAP was continuously determined from the maximum and minimum pressures using an integrator. Nitroglycerin (10 μg/kg) was injected as a bolus into the left femoral vein. This dose usually caused a 25-30% decrease in BP. The test parameters (BP, RAP, and flows in the superior and inferior venae cavae) were recorded with an N-338-8P ink-pen recorder.

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The data were statistically analyzed by Student's *t* test and with both original and standard Axum 5.0 and Math. Soft. Inc. software.

RESULTS

In most cats (n=11) blood flow increased in the superior vena cava and decreased in the inferior vena cava over the first 20 sec postinjection (10 μg/kg nitroglycerin; Fig. 1). In other words, nitroglycerin induced opposite shifts in the superior and inferior vena cava flows. In one cat nitroglycerin did not change cava flows, and, in one cat blood flow decreased in the superior vena cava and increased in the inferior vena cava. The maximum amplitude of flow shifts in the superior vena cava (23±6%) was observed on the 12th sec postinjection (Fig. 1), but after 40 sec these parameters returned to the initial level (56±4 ml/min). During subsequent 40 sec the flow slightly decreased (by 3±2%), but these changes were insignificant. Blood flow in the inferior vena cava decreased immediately after infusion of nitroglycerine, reached a minimum (11±2%) after 20 sec, and returned to its initial level (132±10 ml/min) only 180 sec postinjection (Fig. 1). Thus, the shifts in superior vena cava flow preceded the corresponding shifts in the inferior vena cava flow.

Since venous return was determined as the algebraic sum of the flows in two caval veins, its variations depended on the proportion between flow shifts in the superior and inferior venae cavae and on the dynamics of these changes. Thus, 8-12 sec after infusion of nitroglycerine venous return insignificantly increased (by 1.6±1.5%, p>0.5) due to the rise in the superior vena cava flow. Then (after 40 sec) venous return slightly decreased (by 5±2%) due to the decrease in blood flow in the inferior vena cava and recovery of the superior vena cava flow. Venous return reached its minimum (-7±1.5%) at 80 sec postinjection and returned to the initial level on minute 3 (to 188±12 ml/min), which was similar to the dynamics of the inferior vena cava flow. Thus, although the changes in venous return in response to intravenous infusion of nitroglycerin were characterized by a biphase dynamics, they were determined predominantly by flow changes in the inferor vena cava, because the initial blood flow in this vein (132±10 ml/min) 2-3-folds surpassed that in the superior vena cava (56±4 ml/min).

Reduction in venous return induced by nitroglycerin was accompanied by either decrease (group 1, n=4) or increase in RAP (group 2, n=7). In 2 cats, no changes in RAP were observed in response to nitroglycerin. The maximum amplitude of RAP shifts in both groups (-8±2 and 22±5%, respectively, Table 1) was observed 8-12 sec postinjection. RAP changed

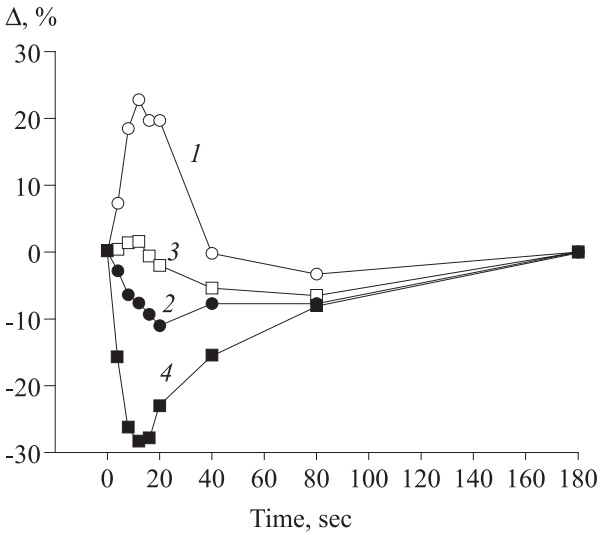

Fig. 1. Dynamics of changes in the superior (*1*) and inferior vena cava flows (*2*), venous return (*3*), and right atrial pressure (*4*) after intravenous infusion of nitroglycerin (10 μg/kg) in cats. Ordinate: relative changes (in % of the initial levels).

synchronously with flow shifts in the superior vena cava, which were positive in all animals (Table 1, Fig. 2). At the same time, the dynamics of RAP differed significantly from those of inferior vena cava flow and venous return. Thus, RAP returned to the initial value (4.9±0.5 mm Hg) 40 sec postinjection, while blood flow in the inferior vena cava and total venous return remained decreased (Fig. 2). At the same time, the flow in the superior vena cava was close to its initial value. Thus, similarly to responses to pressor stimuli [2], the dynamics and magnitude of RAP shifts did not correlate with changes in venous return. These findings suggest the existence of intrinsic intracardiac mechanisms of RAP regulation [1]. It is noteworthy that the two groups of cats with opposite RAP responses demonstrated similar quantitative and temporal characteristics of blood flow changes in both venae cavae, as well as in total venous return (Fig. 2).

Nitroglycerin induced a decrease in BP, which developed synchronously with blood flow increase in the superior vena cava. The minimum RAP (108±10 mm Hg,

TABLE 1. Dynamics of Negative or Positive Shifts in RAP (% of Initial Level) in Response to Intravenous Infusion of Nitroglycerin (10 μg/kg) in Cats (M±m)

Groups	Time, sec			
	8	12	40	80
Group 1 (n=4)	-8±2	-8±3	0	0
Group 2 (n=7)	22±5	8±3	3±3*	-1±1*

Note. Group 1: animals responded by a reduction of right atrial pressure; group 2: animals responded by an increase in right atrial pressure; n: number of animals. *p>0.05 compared to the initial level.

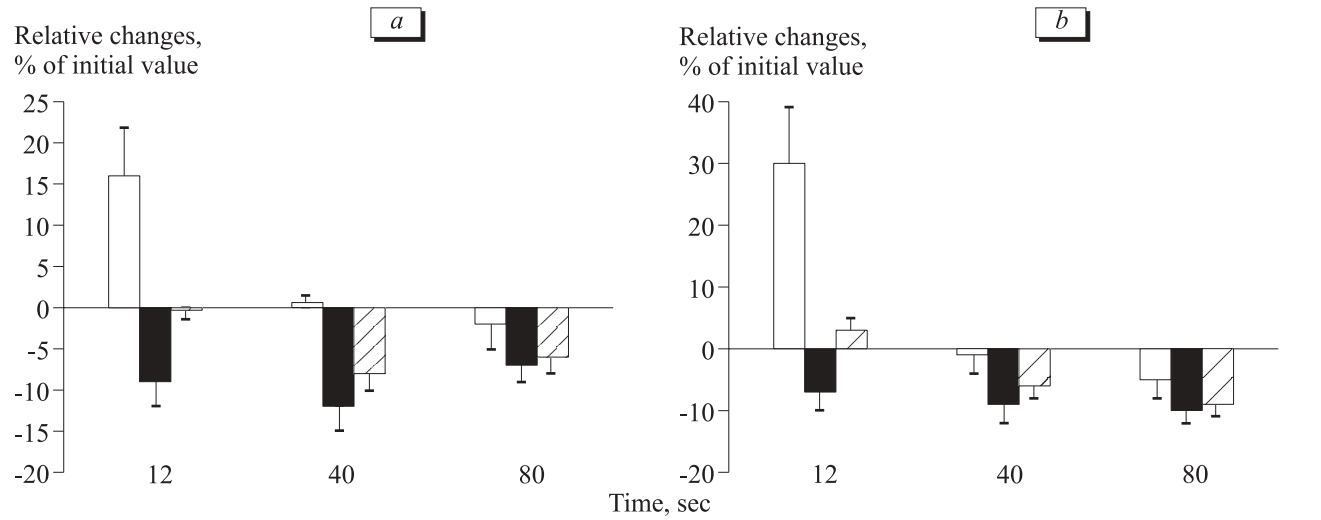

Fig. 2. Dynamics of changes in superior (light columns) and inferior (dark columns) vena cava flows and venous return (dashed columns) after intravenous infusion of nitroglycerin (10 μg/kg) in cats.

-28±4% below the initial level) was observed 12 sec postinjection, when the superior vena cava flow reached its maximum, i.e. changes in these parameters were opposite (Fig. 1). During the first 40 sec postinjection, the dynamics of RAP practically mirrored flow dynamics in the superior vena cava (Fig. 1). When superior vena cava flow returned to the initial value (80 sec), RAP, inferior vena cava flow, and venous return remained decreased (by 8±3, -8±2, and -7±1.5%, respectively; $p<0.05$, Fig. 1). The mechanisms of these RAP shifts induced by nitroglycerine have to be specially studied taking into consideration the peculiarities of arterial vascular bed response.

Thus, our experiments showed that nitroglycerin usually increases blood flow in the superior vena cava, decreases it in the inferior vena cava, and reduces total venous return. Flow changes in the superior vena cava preceded those in the inferior vena cava. Consequently, at later terms the temporal and quantitative dynamics of total venous return depend primarily on the shifts in inferior vena cava flow. Under these conditions, RAP can either increase, or decrease. In addition, the dynamics of RAP recovery to the initial level is faster, compared with venous return, and corresponds to the time course of flow changes in the superior vena cava.

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